engine superchargers

Supplement to Select STST Courses

STST
Service Technician Specialty Training
Ford
Ford Parts and Service Division
Technical Training

IMPORTANT SAFETY NOTICE

Appropriate service methods and proper repair procedures are essential for the safe, reliable operation of all motor vehicles, as well as the personal safety of the individual doing the work. This manual provides general directions for accomplishing service and repair work with tested, effective techniques. Following them will help assure reliability.

There are numerous variations in procedures, techniques, tools, and parts for servicing vehicles, as well as in the skill of the individual doing the work. This manual cannot possibly anticipate all such variations and provide advice or cautions as to each. Accordingly, anyone who departs from instructions provided in this manual must first establish that he compromises neither his personal safety nor the vehicle integrity by his choice of methods, tools or parts.

As you read through the procedures, you will come across NOTES, CAUTIONS, AND WARNINGS. Each one is there for a specific purpose. NOTES give you added information that will help you to complete a particular procedure. CAUTIONS are given to prevent you from making an error that could damage the vehicle. WARNINGS remind you to be especially careful in those areas where carelessness can cause personal injury. The following list contains some general WARNINGS that you should follow when you work on a vehicle.

- Always wear safety glasses for eye protection.
- Use safety stands whenever a procedure requires you to be under the vehicle.
- Be sure that the ignition switch is always in the OFF position, unless otherwise required by the procedure.
- Set the parking brake when working on the vehicle. If you have an automatic transmission, set it in PARK unless instructed otherwise for a specific service operation. If you have a manual transmission, it should be in REVERSE (engine OFF) or NEUTRAL (engine ON) unless instructed otherwise for a specific service operation.
- Operate the engine only in a well-ventilated area to avoid the danger of carbon monoxide.
- Keep yourself and your clothing away from moving parts when the engine is running, especially the fan and belts.
- To prevent serious burns, avoid contact with hot metal parts such as the radiator, exhaust manifold, tail pipe, catalytic converter and muffler.
- Do not smoke while working on the vehicle.
- To avoid injury, always remove rings, watches, loose hanging jewelry, and loose clothing before beginning to work on a vehicle. Tie long hair securely behind your head.
- Keep hands and other objects clear of the radiator fan blades. Electric cooling fans can start to operate at any time by an increase in underhood temperatures, even though the ignition is in the OFF position. Therefore, care should be taken to ensure that the electric cooling fan is completely disconnected when working under the hood.

The recommendations and suggestions contained in this manual are made to assist the dealer in improving his dealership parts and/or service department operations. These recommendations and suggestions do not supersede or override the provisions of the Warranty and Policy Manual, and in any cases where there may be a conflict, the provisions of the Warranty and Policy Manual shall govern.

The descriptions, testing procedures, and specifications in this handbook were in effect at the time the handbook was approved for printing. Ford Motor Company reserves the right to discontinue models at any time, or change specifications, design, or testing procedures without notice and without incurring obligation. Any reference to brand names in this manual is intended merely as an example of the types of tools, lubricants, materials, etc. recommended for use. Equivalents, if available, may be used. The right is reserved to make changes at any time without notice.

WARNING: Many brake linings contain asbestos fibers. When working on brake components, avoid breathing the dust. Breathing asbestos dust can cause asbestosis and cancer.

Breathing asbestos dust is harmful to your health.

Dust and dirt present on car wheel brake and clutch assemblies may contain asbestos fibers that are hazardous to your health when made airborne by cleaning with compressed air or by dry brushing.

Wheel brake assemblies and clutch facings should be cleaned using a vacuum cleaner recommended for use with asbestos fibers. Dust and dirt should be disposed of in a manner that prevents dust exposure, such as sealed bags. The bag must be labelled per OSHA instructions and the trash hauler notified as to the contents of the bag.

If a vacuum bag suitable for asbestos is not available, cleaning should be done wet. If dust generation is still possible, technicians should wear government approved toxic dust purifying respirators.

OSHA requires areas where asbestos dust generation is possible to be isolated and posted with warning signs. Only technicians concerned with performing brake or clutch service should be present in the area.

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INTRODUCTION

THE PURPOSE OF THIS REFERENCE BOOK

This reference book is designed to familiarize you with the fundamentals of superchargers.

It is divided into four sections:

- Introduction to Supercharging
- Principles of Supercharging
- Description and Operation
- Glossary

OBJECTIVES

- To explain the fundamentals of supercharging and its application in the automotive industry.
- To distinguish between superchargers and turbochargers.
- To review the theory and operation of a supercharged engine.
- To identify the different types of superchargers used in the automotive field.
- To explain how each type of supercharger operates.

INTRODUCTION TO SUPERCHARGING

ENGINE POWER AND SUPERCHARGING

In the years since the internal combustion engine was invented, many attempts have been made to improve its performance. Engine power has always been a major concern when designing a vehicle. The reason is simple: the more power supplied to a vehicle, the quicker its response. A vehicle with a powerful engine can go faster than one with a weak engine, and can also reach a desired speed in a shorter amount of time (figure 1).

Figure 1. More Power = More Speed

INTRODUCTION TO SUPERCHARGING

One way to increase engine power is to increase the size of the engine. Making an engine larger allows more fuel to be consumed and thus more power to be produced. However, a large engine weighs more than a small engine. It requires a stronger vehicle frame for support, and also needs a bigger engine compartment. All of these factors lower the fuel economy of the vehicle and add to manufacturing costs (figure 2).

Another way to increase engine power is to modify the basic engine and fuel system components. For instance, a larger carburetor (two venturi instead of one) or a well-designed injector will provide a better air-fuel mixture. A piston made of high-quality material can compress the air-fuel mixture into a smaller area and withstand the greater force of combustion. These types of improvements will allow an engine to produce more power, but the increase is likely to be small (figure 3).

Figure 3. Modify Engine And Fuel System Components

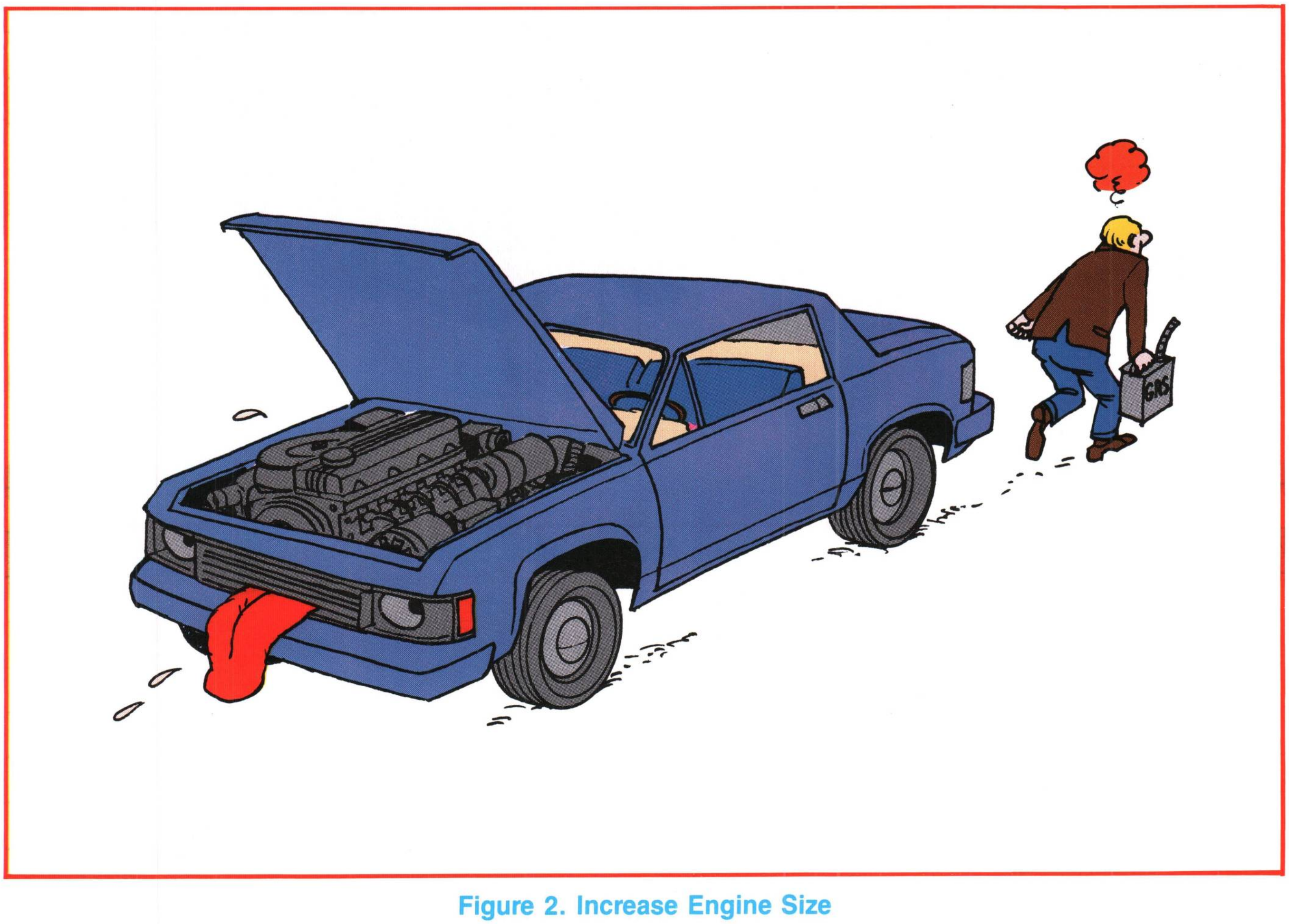

Figure 2. Increase Engine Size

INTRODUCTION TO SUPERCHARGING

Yet another way to enhance engine power is to improve the air intake system. The internal combustion engine is basically an air pump. Air is drawn in and mixed with fuel. This mixture is ignited, and the resulting exhaust gases are pumped out of the system. The mixture of air and fuel is often called an air-fuel charge. When ignited, this charge creates the force which drives the pistons. The more air-fuel charge given to an engine, the more power it is able to produce (figure 4). Without external help, an engine receives only a partial air-fuel charge. This is mainly due to bends and restrictions along the intake path and leftover exhaust in the cylinder. An effective solution is to *pump* air into the engine, giving it a *super* charge. By forcing more air into the cylinders, an engine can burn more fuel and produce more power (figure 5). This method of pumping air into an engine is called supercharging. There are two different devices used for supercharging an engine: a turbocharger, and a supercharger. The difference between the two is the power source which drives them.

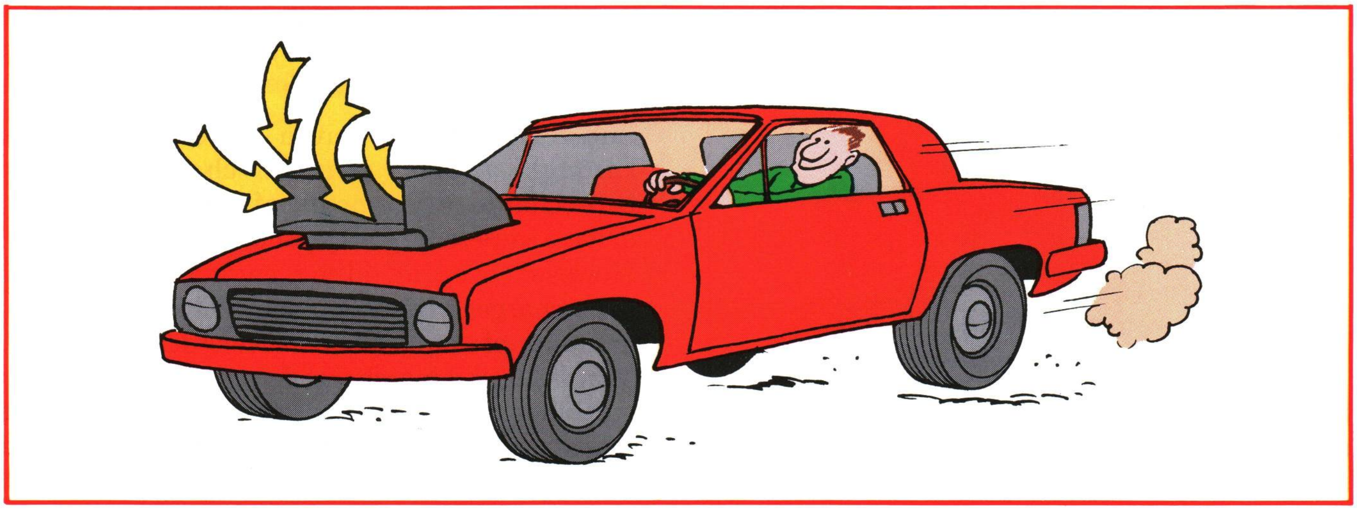

Figure 4. Improve The Air Intake System

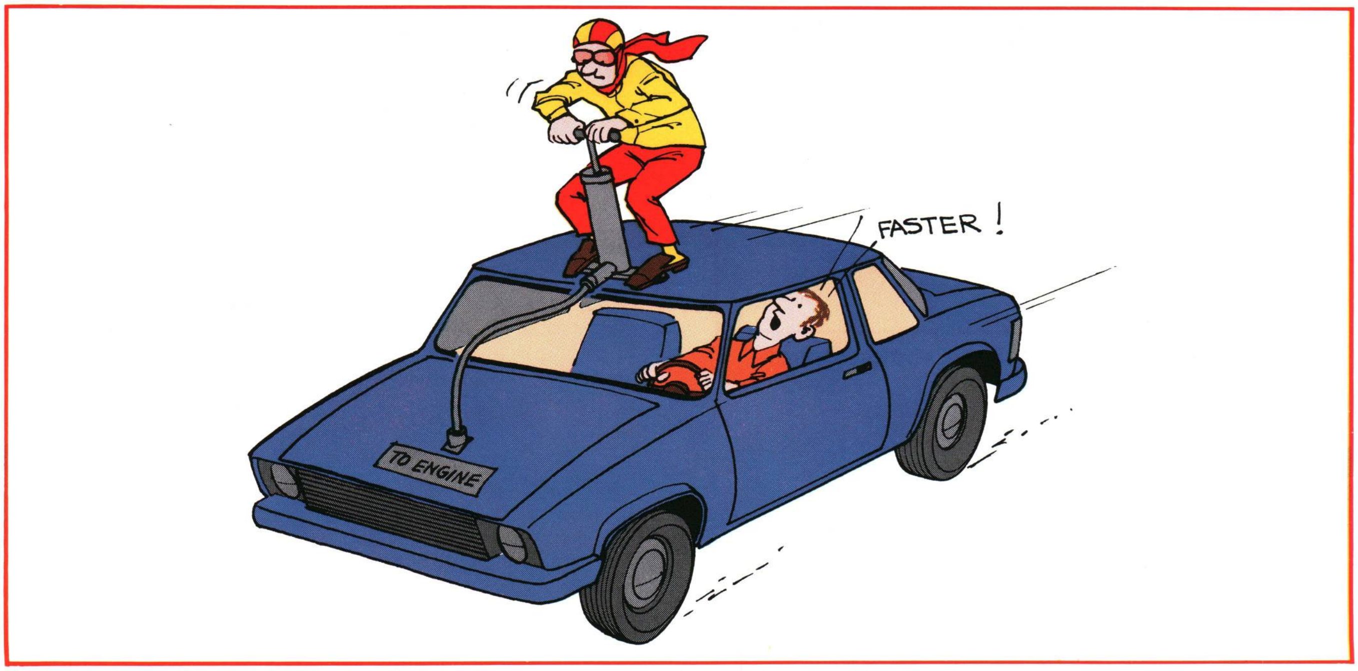

Figure 5. Pump Air In...Supercharge The Engine

TURBOCHARGERS AND SUPERCHARGERS

Turbochargers are driven by the exhaust pumped out of an engine (figure 6). The amount of exhaust available to drive a turbocharger depends on engine speed. When the throttle is almost closed, an engine receives a lean air-fuel mixture and idles at a slow rpm. An engine pumps out little exhaust during idle operation. When the throttle is wide-open, an engine receives a rich air-fuel mixture and its speed increases. As the speed of an engine increases, more exhaust is pumped out. For this reason, turbochargers operate best at high engine speeds.

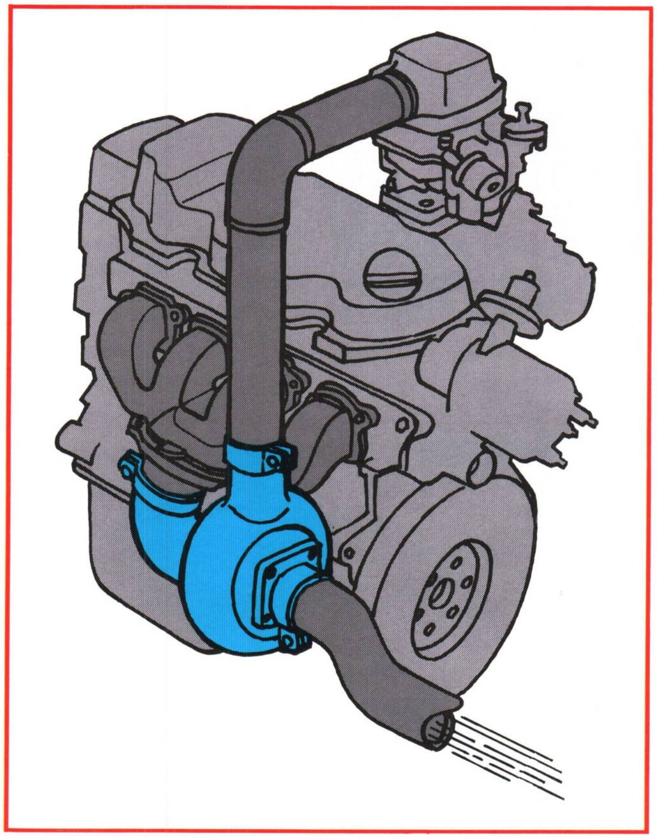

Figure 6. Turbochargers Are Exhaust-Driven

One drawback to turbocharging is that an idling engine does not pump enough exhaust to sufficiently drive the turbocharger. This is most noticeable when a turbocharged vehicle accelerates from a standstill. There is a short interval of time before the turbocharger begins to pump a large amount of air into the engine. This short interval of time is called turbo lag. During this period of turbo lag, the vehicle does not receive the extra engine power that a turbocharger helps provide at higher speeds (figure 7). A supercharged vehicle, on the other hand, does not have turbo lag. This is due to the fact that superchargers are not driven by exhaust gases. The power source of a supercharger is the engine itself.

Superchargers are driven by the crankshaft through a belt, gear or chain. Like the turbocharger, the amount of power available to drive a supercharger depends on engine speed. However, even an idling engine provides the supercharger with enough power to pump a large amount of air. When accelerating from a standstill, a supercharged vehicle immediately receives extra engine power (figure 8). Though it takes engine power to drive a supercharger, a supercharger will help an engine produce much more power in return. As you will see, a supercharged engine can easily produce fifty percent more power than the same engine without a supercharger.

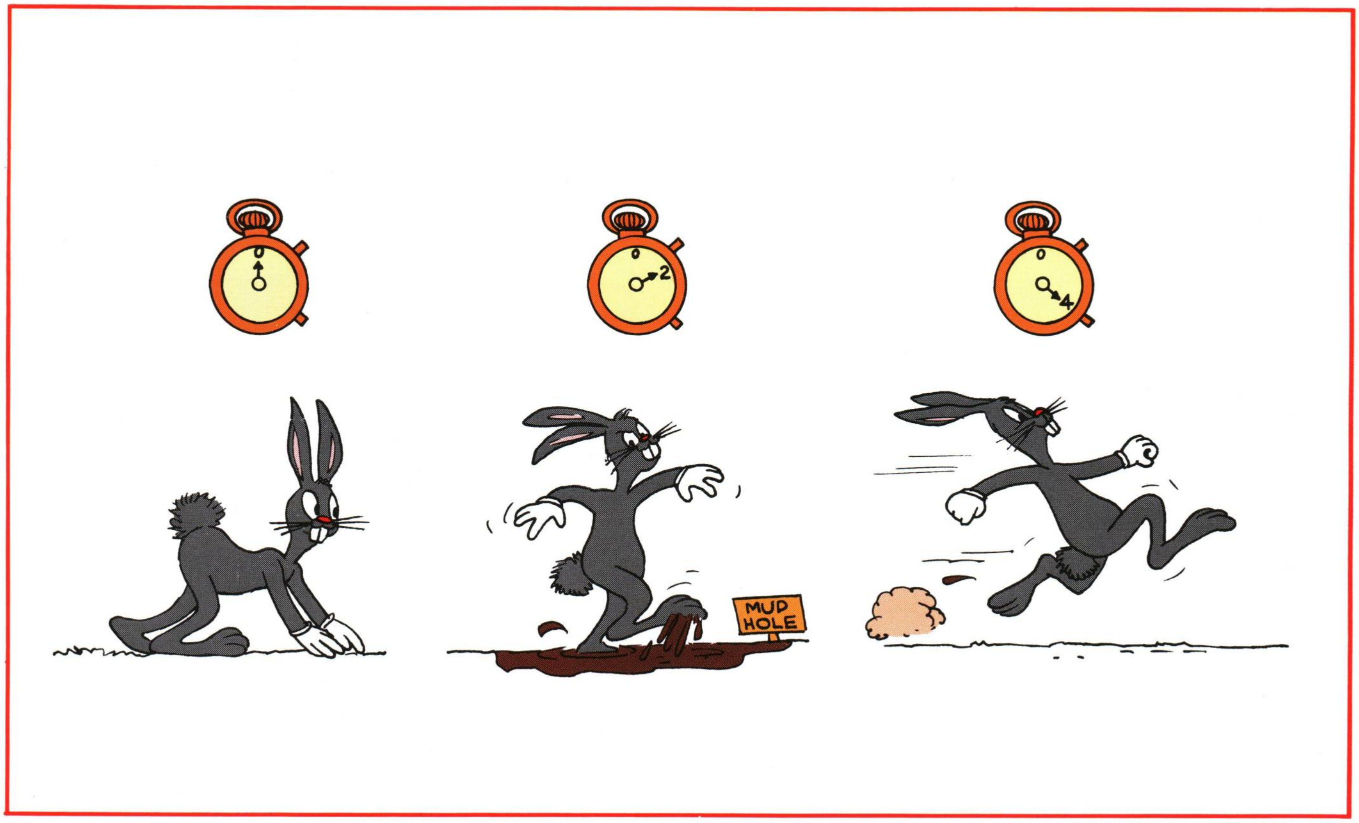

Figure 7. Turbochargers Have Turbo Lag

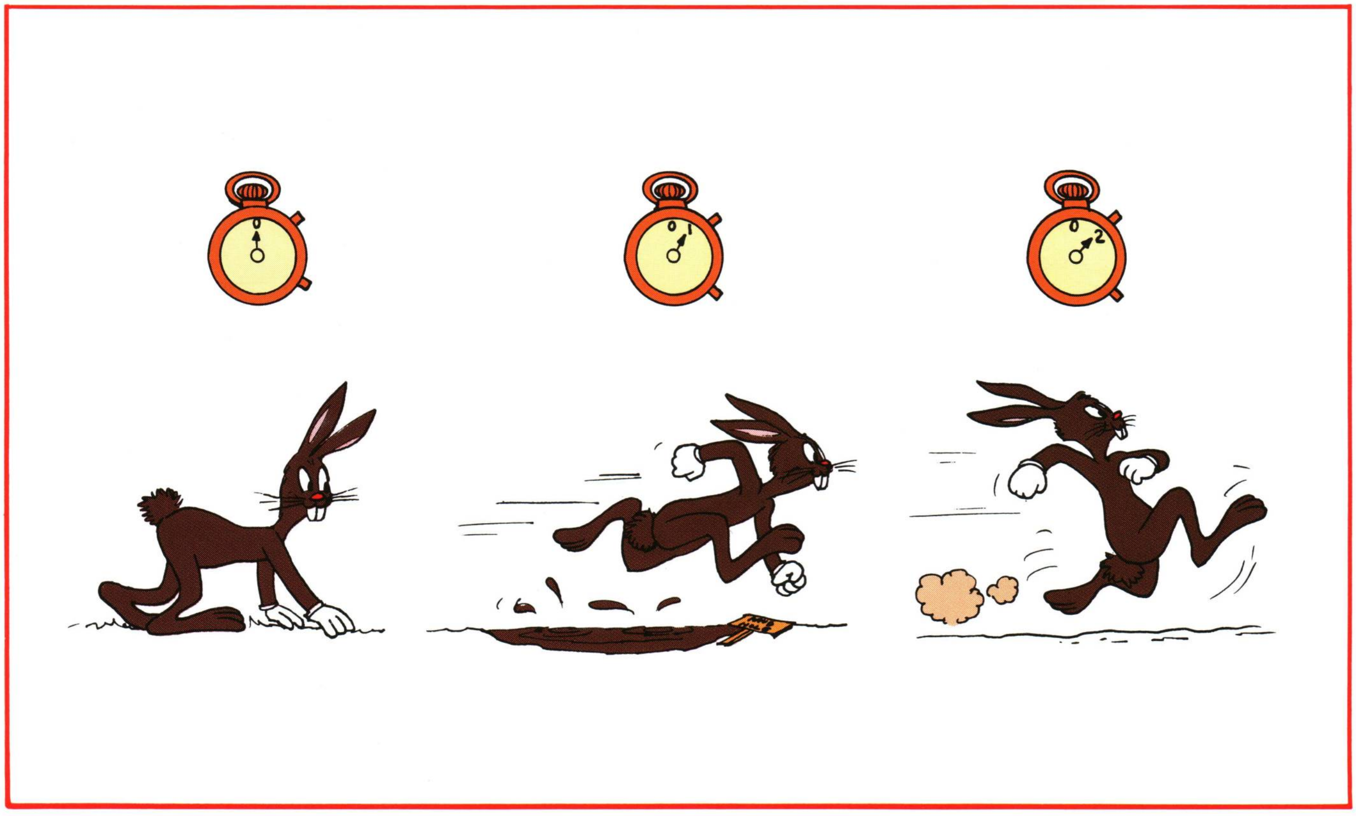

Figure 8. Superchargers Have No Turbo Lag

INTRODUCTION TO SUPERCHARGING

HISTORY OF SUPERCHARGER DEVELOPMENT

Supercharging is an effective way to increase the power of an automotive engine. In fact, supercharging is not limited to automotive applications. Superchargers have been used on aircraft engines, boats, diesel trains, and stationary engines for many years (figure 9).

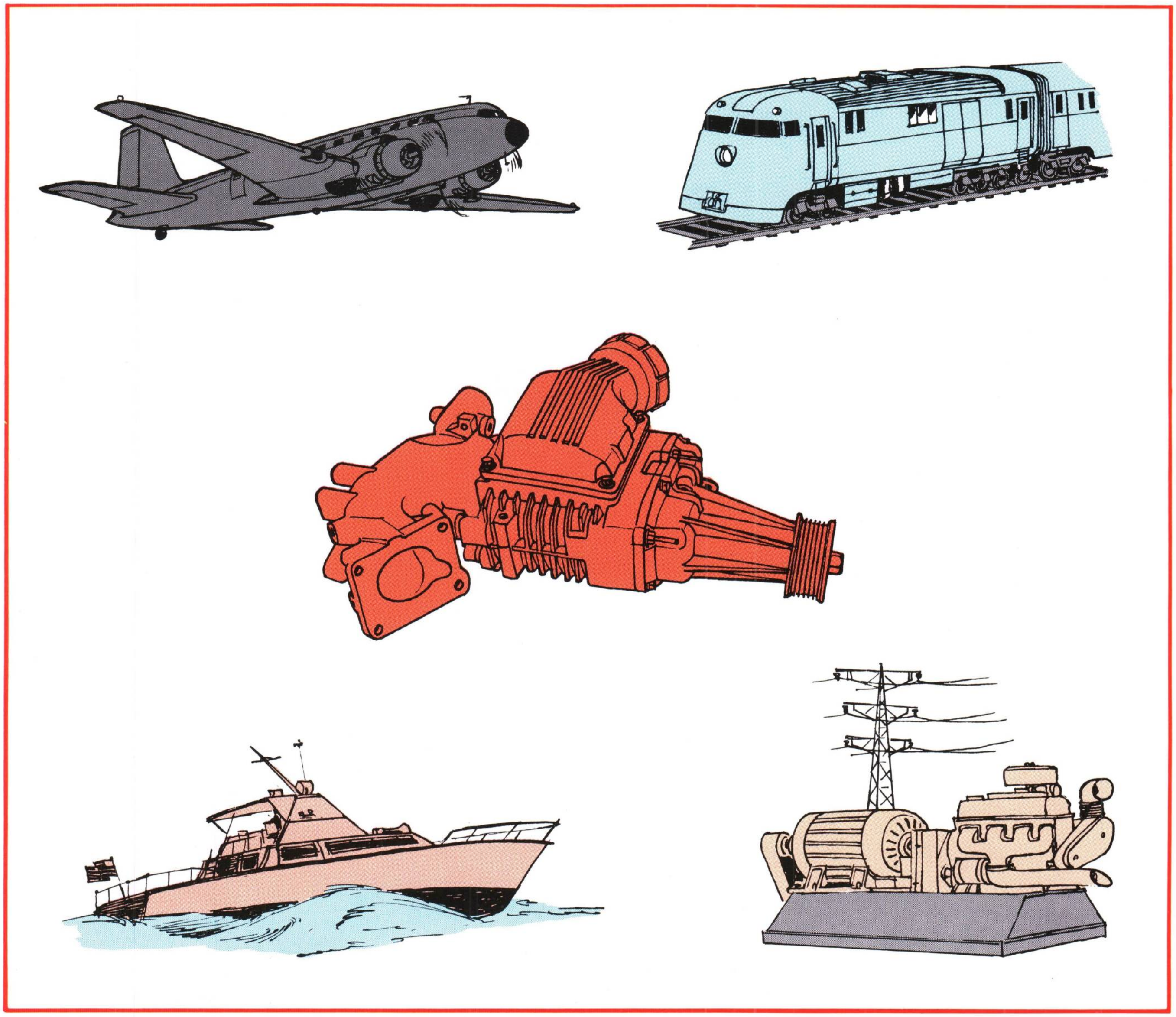

Figure 9. Supercharger Applications

INTRODUCTION TO SUPERCHARGING

The first example of automotive supercharging in the United States was in 1907 when Lee Chadwick, owner of the Chadwick automobile firm, mounted a supercharger to one of his Great Chadwick Sixes. He was one of the first to realize that pumping air into the cylinders would provide more engine power. The supercharger was driven by a leather belt attached to the flywheel (figure 10).

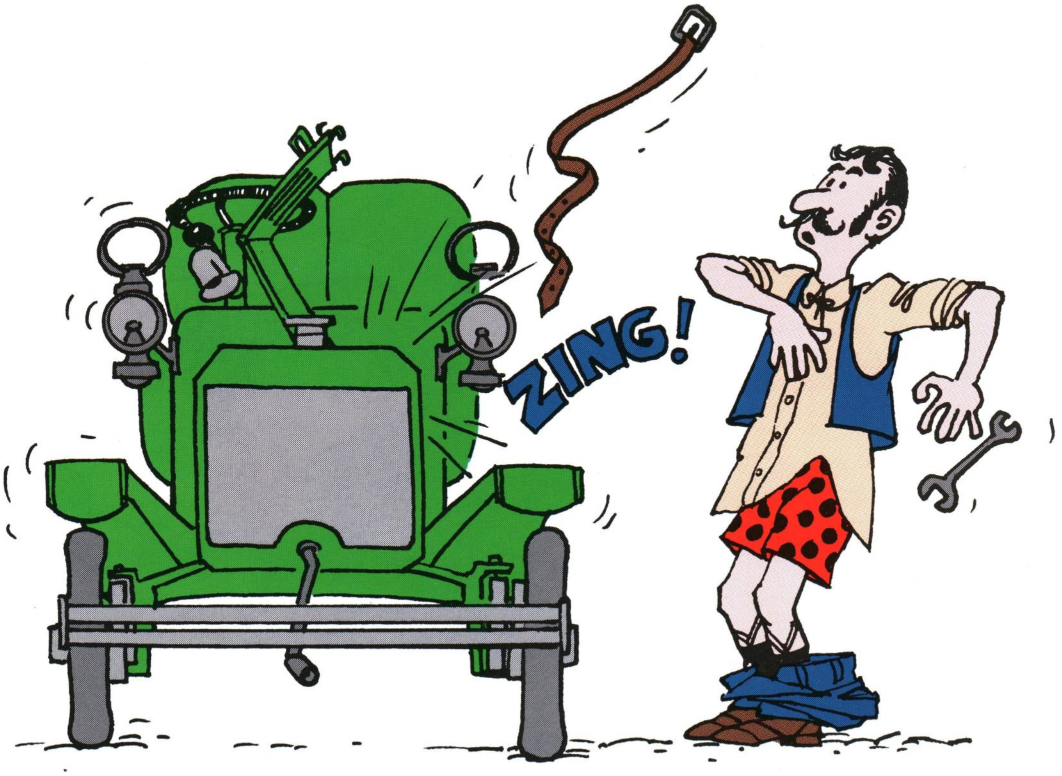

Figure 10. Early Automotive Superchargers Were Belt-Driven

INTRODUCTION TO SUPERCHARGING

Scientific exploration of supercharging began as early as 1916 in response to the needs of wartime aircraft. The higher an airplane flies, the less dense the surrounding atmosphere becomes. Supercharging was important during both World Wars because the plane which could fly the highest had an advantage over its enemies. Superchargers were used to maintain engine power at high altitudes by forcing a denser charge into the cylinders (figure 11).

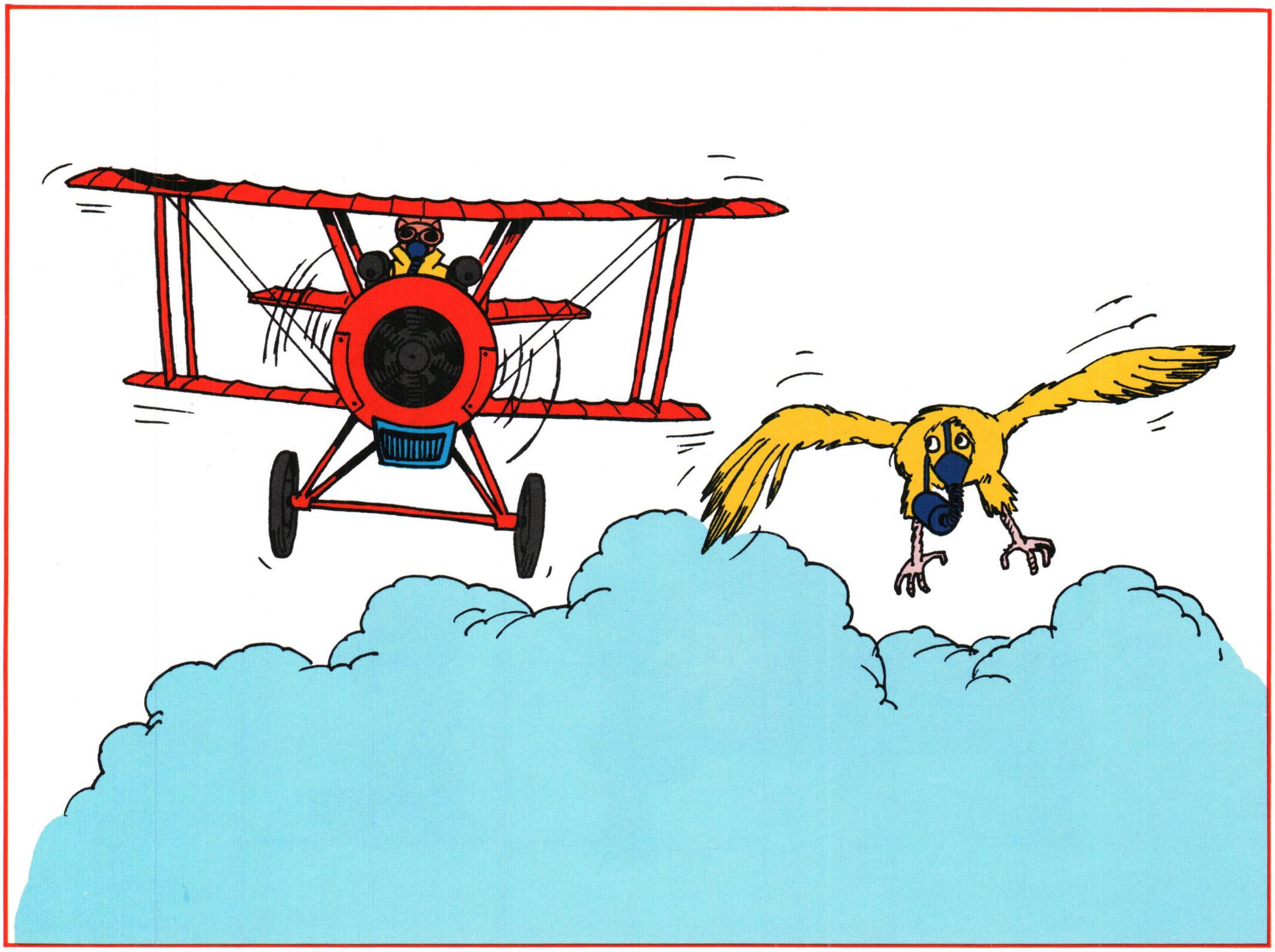

Figure 11. At High Altitudes, Everything Needs More Oxygen

INTRODUCTION TO SUPERCHARGING

For many years, supercharging has played a large role in auto racing. By mounting a supercharger on an engine, race car designers found that they could boost the intake air pressure and improve engine performance. The development of superchargers for auto racing went in several directions. In Europe, the turning, twisting road courses like the Gran Prix require good low-end torque and instant throttle response. American race tracks such as the Indy 500 feature long, fast ovals with sweeping curves, requiring a tight rpm range at wide-open throttle. Both Europeans and Americans designed superchargers which were best suited for their particular style of racing (figure 12).

Today, there are several different types of superchargers. But no matter how a supercharger is designed, its main purpose is to force more air into the cylinders and help the engine provide more power. To have a clear understanding of how a supercharger works, it is important to recall the basic principles of the four-stroke cycle.

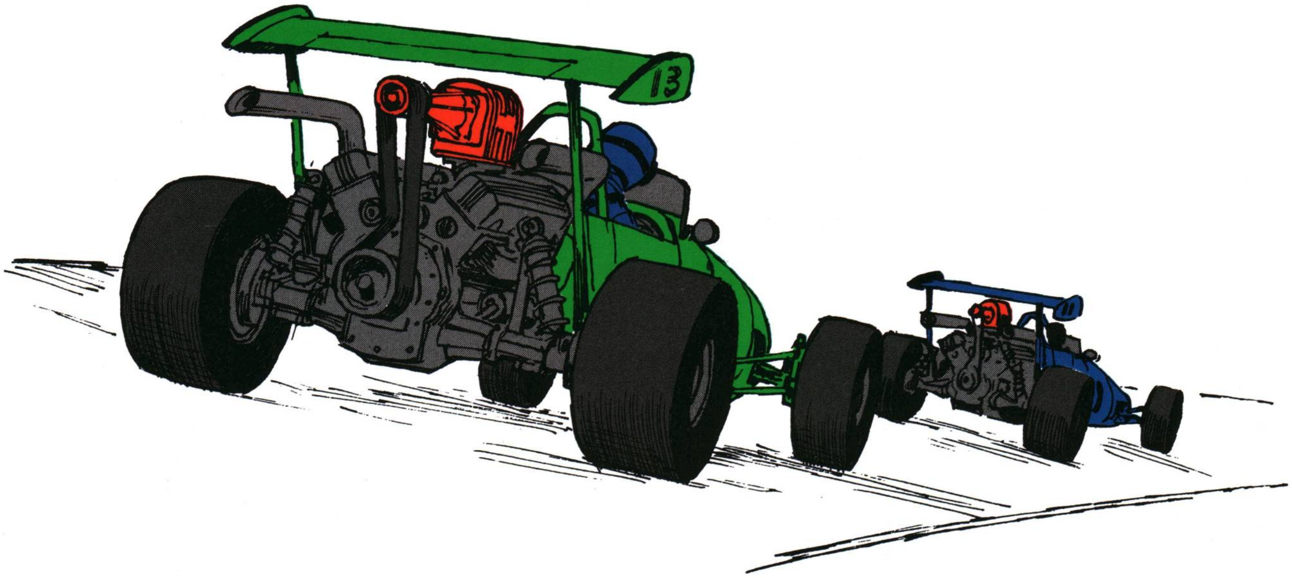

Figure 12. Supercharged Race Cars

PRINCIPLES OF SUPERCHARGING

FOUR-STROKE CYCLE

Most gasoline engines have a four-stroke cycle design. During this cycle, the crankshaft completes two full revolutions. Figures 13 through 16 illustrate the four piston strokes which make up this cycle.

Intake Stroke

The piston is drawn down by the momentum of the crankshaft (figure 13). The intake port is open, and the vacuum caused by the movement of the piston draws the air-fuel charge into the cylinder. When the piston finishes its downward stroke, the intake valve closes the intake port, so that the air-fuel charge cannot escape.

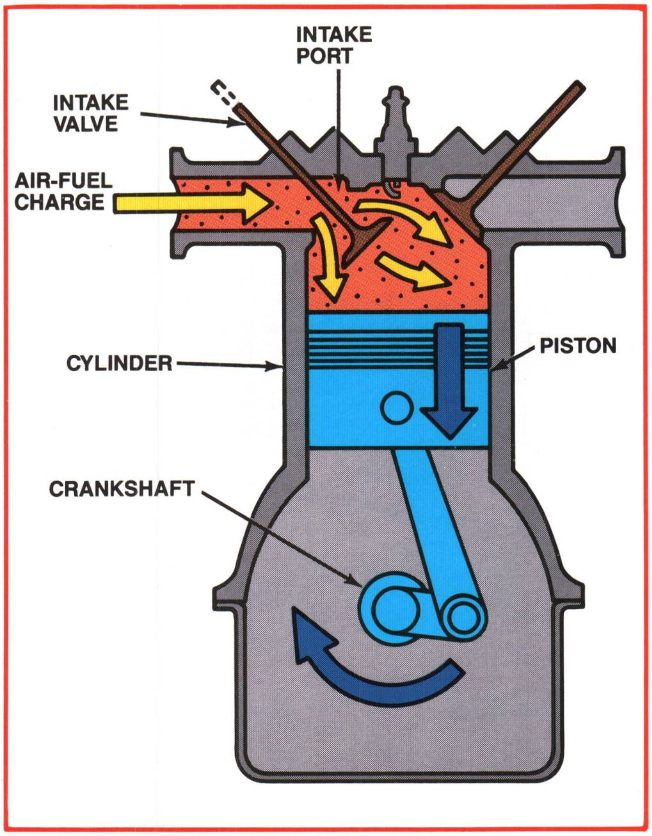

Figure 13. Intake Stroke

Compression Stroke

The piston moves upward in the cylinder, due to the momentum of the crankshaft (figure 14). During this stroke, both the intake and exhaust ports remain closed. As the piston moves upward, the amount of free space in the cylinder decreases. Since there is no place for the air-fuel charge to escape, it is trapped in the cylinder and becomes compressed to an eighth or a ninth of its original volume.

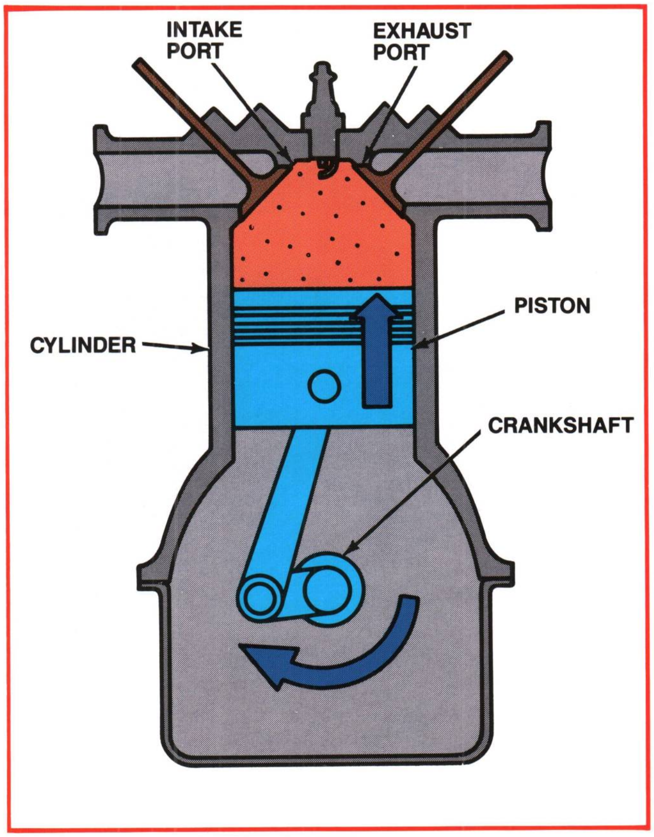

Figure 14. Compression Stroke

Power Stroke

As the piston completes its upward stroke, the compressed charge is ignited (figure 15). The resulting burst of power drives the piston downward, providing the energy needed to turn the crankshaft. Both the intake and exhaust ports remain closed.

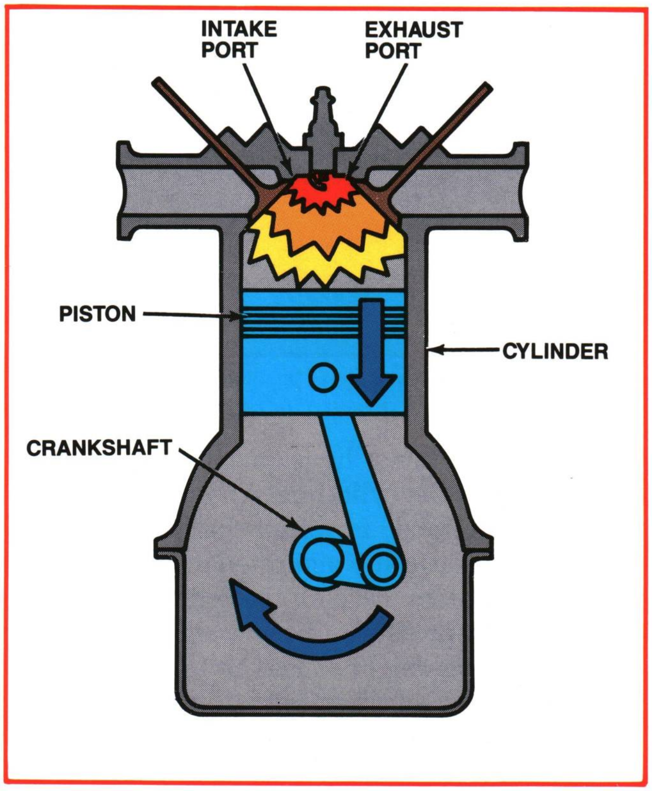

Figure 15. Power Stroke

Exhaust Stroke

After the piston completes its downward stroke, the momentum of the crankshaft pushes the piston back up the cylinder. As the piston begins to move upward, the exhaust valve opens the exhaust port (figure 16). Exhaust gases are forced out of the cylinder by the piston. As the piston completes its upward stroke, the exhaust port is closed and the intake port is opened, and the cycle repeats.

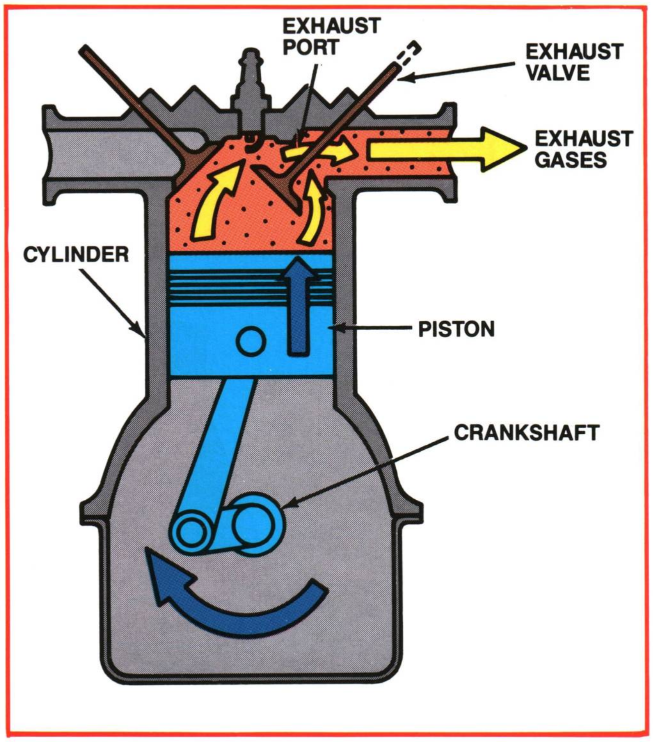

Figure 16. Exhaust Stroke

AIR INTAKE SYSTEM

The force of an ignited air-fuel charge largely depends on the density of the charge. Density is the mass of a substance in a region of space. As an example, think of density as how tightly a substance is packed into a container (figure 17). For our purposes, the substance is a mixture of air and fuel being packed into a cylinder. The more tightly we pack the air-fuel charge into a cylinder, the greater the force of the ignited charge and the more power the engine produces.

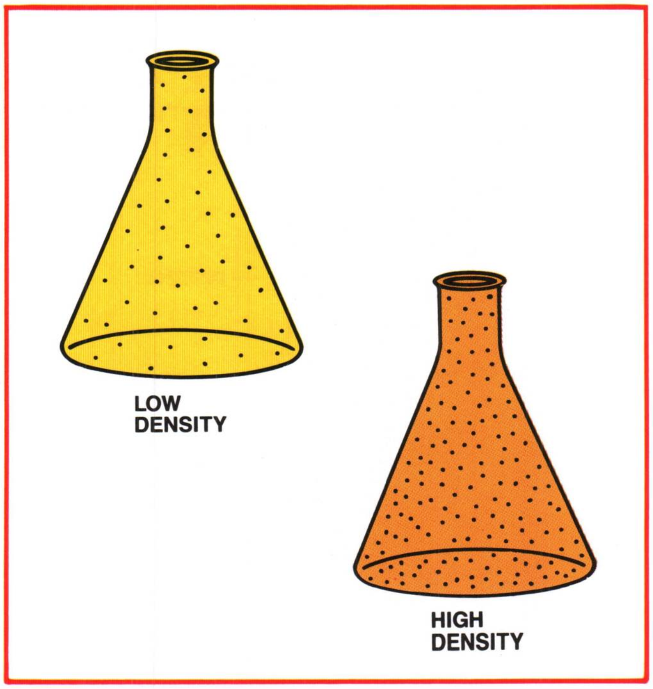

Figure 17. Density

To increase the density of an air-fuel charge, the cylinders must receive more air and fuel. Providing the cylinders with more fuel is not a problem. More fuel can be added to the intake airstream. But for proper combustion, the proportion of air and fuel must be kept within a certain range. As an example, each gallon of fuel requires about 9000 gallons of air during part throttle operation (figure 18). If too much fuel is mixed with the air, engine and emission control components can be damaged. The amount of fuel added is therefore limited by the amount of air which enters the cylinder during an intake stroke.

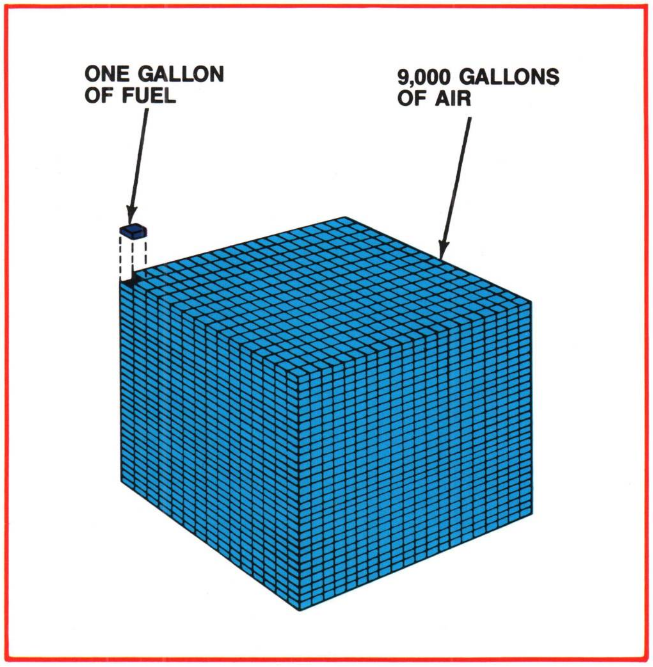

Figure 18. Average Air-Fuel Mixture

Many engines do not have an external device to pump air into the cylinders. An engine which is not supercharged is often called naturally aspirated. A naturally aspirated engine relies on atmospheric pressure to fill the cylinders with air. Atmospheric pressure is the weight of the air around us. This weight causes air to press against an object from all directions (figure 19).

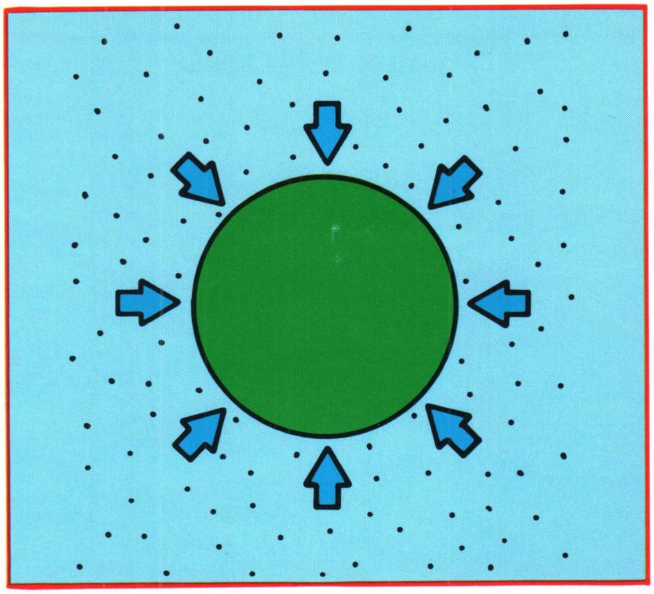

Figure 19. Atmospheric Pressure

PRINCIPLES OF SUPERCHARGING

When a piston moves down the cylinder during its intake stroke, an empty space, or vacuum, is created in the cylinder. Atmospheric pressure forces air to fill up as much of this space as possible. Unfortunately, the air must travel a difficult path to fill up this space. Once the air is filtered, it must pass through the carburetor or throttle body, through the manifold, through the intake port, and finally into the cylinder. The components along this path make up the air intake system. Bends and restrictions throughout the air intake system limit the amount of air which reaches the cylinder before the intake port closes (figure 20). This means the engine is not drawing in the full amount of air that it is capable of drawing in.

A comparison of the amount of air that an engine *could* draw in to the amount that it *actually* draws in under normal operating conditions is called volumetric efficiency. The power output of an engine is directly linked to its volumetric efficiency. A naturally aspirated engine usually has about an 80% volumetric efficiency. This means that the engine draws in about 80% of the air it could draw in. By streamlining passages and increasing port sizes, the volumetric efficiency of a naturally aspirated engine can be improved, but the air will still have difficulty reaching the cylinder. As long as an engine relies on atmospheric pressure to push the air-fuel charge through the intake system, it will not produce as much power as it is capable of producing.

An obvious way to improve volumetric efficiency is to pump air through the intake system. This is exactly what superchargers are designed to do. Instead of loading the cylinders with a partial air-fuel charge, a supercharged engine can fill its cylinders with a charge which meets or exceeds 100% volumetric efficiency.

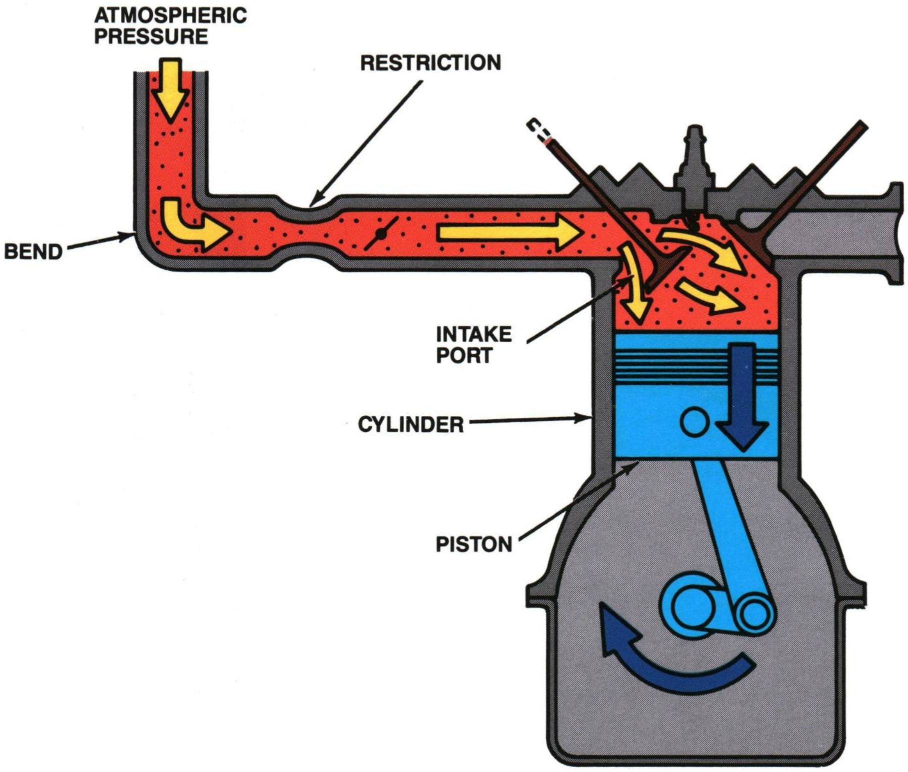

Figure 20. Naturally Aspirated Engine

SUPERCHARGING AN AIR INTAKE SYSTEM

Pumping air into an intake system forces it through the bends and restrictions along the intake path. The forced air travels through the intake system more quickly than it would under normal atmospheric pressure. Since it is moving at a faster rate, more air passes through the intake port before it closes. More fuel can be added, and the cylinder receives a denser charge (figure 21). This is the basic principle behind supercharging an air intake system.

As an example, a 300-cubic-inch supercharged engine usually receives the same amount of air-fuel charge as a 450-cubic-inch naturally aspirated engine. Because the charge of the smaller engine is confined within a smaller combustion chamber, its density is greater than that of the larger engine. This increase in density allows the smaller engine to produce as much power as the larger engine. A supercharged air intake system can help an engine increase its power production by more than 50%.

There are several other advantages to supercharging an engine. During intake and exhaust valve overlap, the pumped air pushes the remaining exhaust out of the combustion chamber. The engine burns a cleaner air-fuel mixture, improving the quality of emissions. The forced airflow and removal of hot exhaust gases also cools the cylinder head, pistons and valves. These factors help extend the life of an engine and its emission control system.

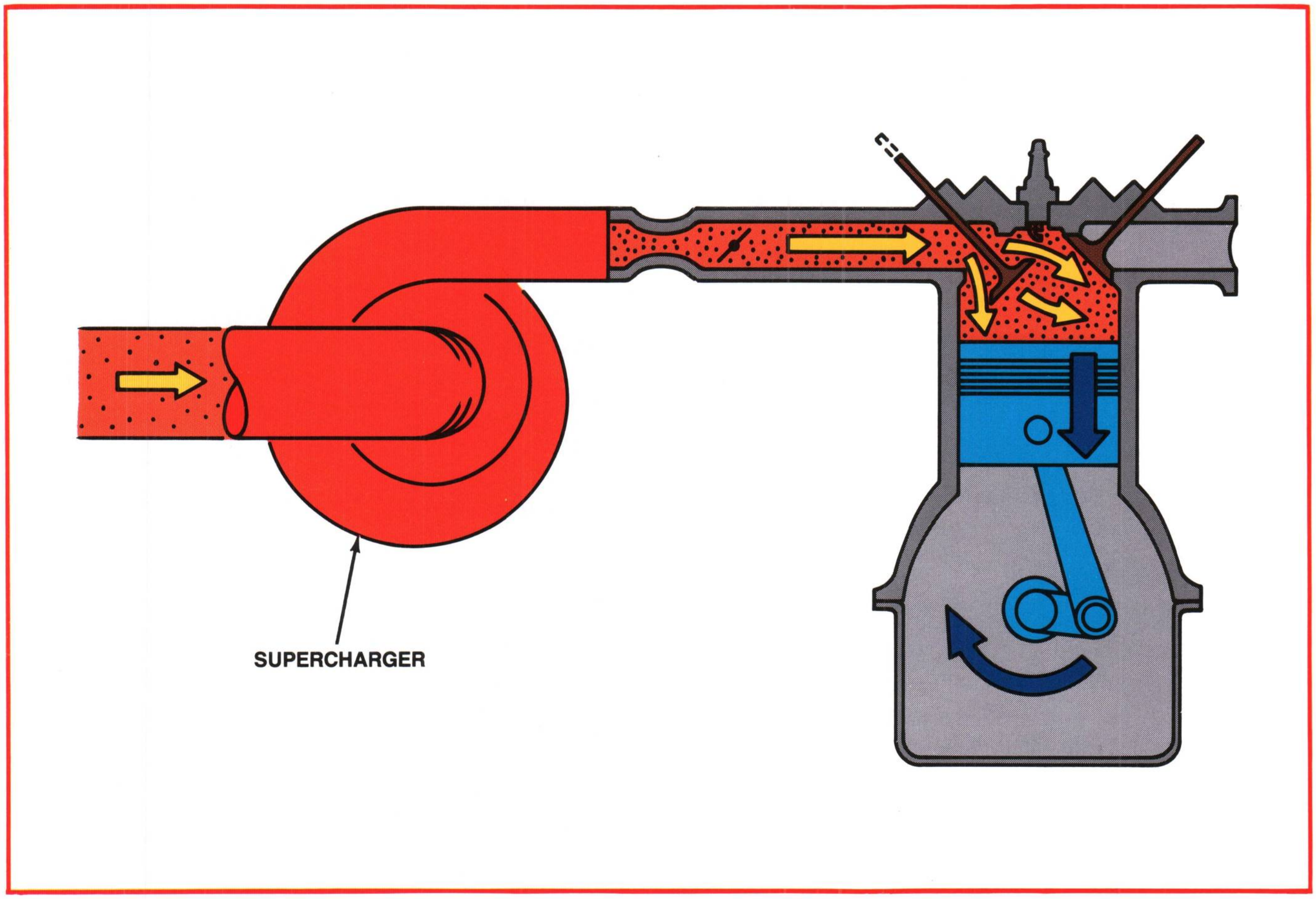

Figure 21. Supercharged Engine

PRINCIPLES OF SUPERCHARGING

Pressure and Temperature

We have already defined density as how tightly a substance is packed. By packing air into the cylinder, the power output of the engine can be increased. There are two variables which determine how tightly the air is packed. These variables are pressure and temperature.

When air is pumped through an intake system, the combustion chamber receives an increase, or boost of air pressure. This boost of pressure is usually measured in pounds per square inch, or psi. Boost pressure helps to increase the air density (figure 22). However, friction heats the air as it moves along the intake path. An increase in temperature tends to decrease air density (figure 23). Since there is more than one variable, an increase in pressure may not always lead to a greater air density.

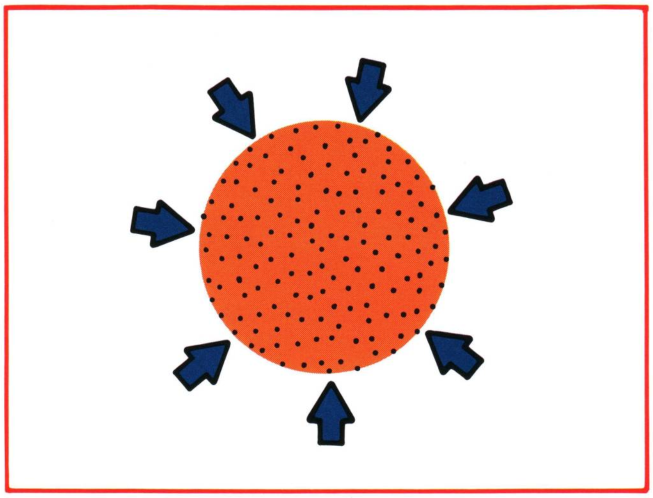

Figure 22. Pressure Increases Air Density

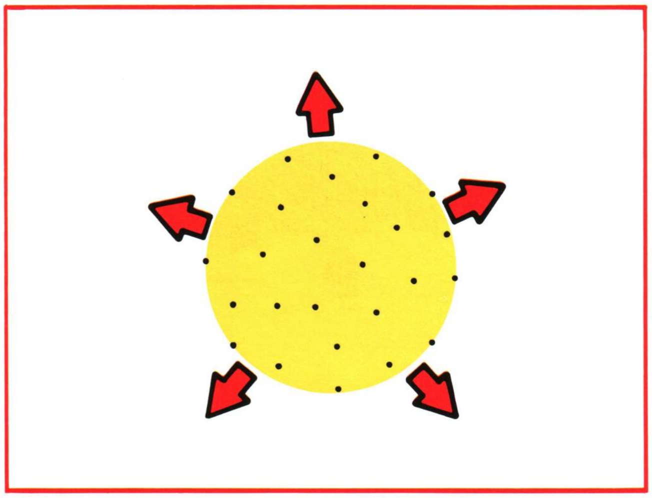

Figure 23. Heat Decreases Air Density

For example, if air is both compressed and heated, the density of air could increase, decrease, or not change at all (figure 24). This is an important consideration, because a supercharger both compresses and heats the air it pumps into the engine. Most superchargers heat the air due to the friction of turbulence. It is important to keep the intake temperature down because an overheated air-fuel charge can lead to premature detonation in the combustion chamber and possible component damage.

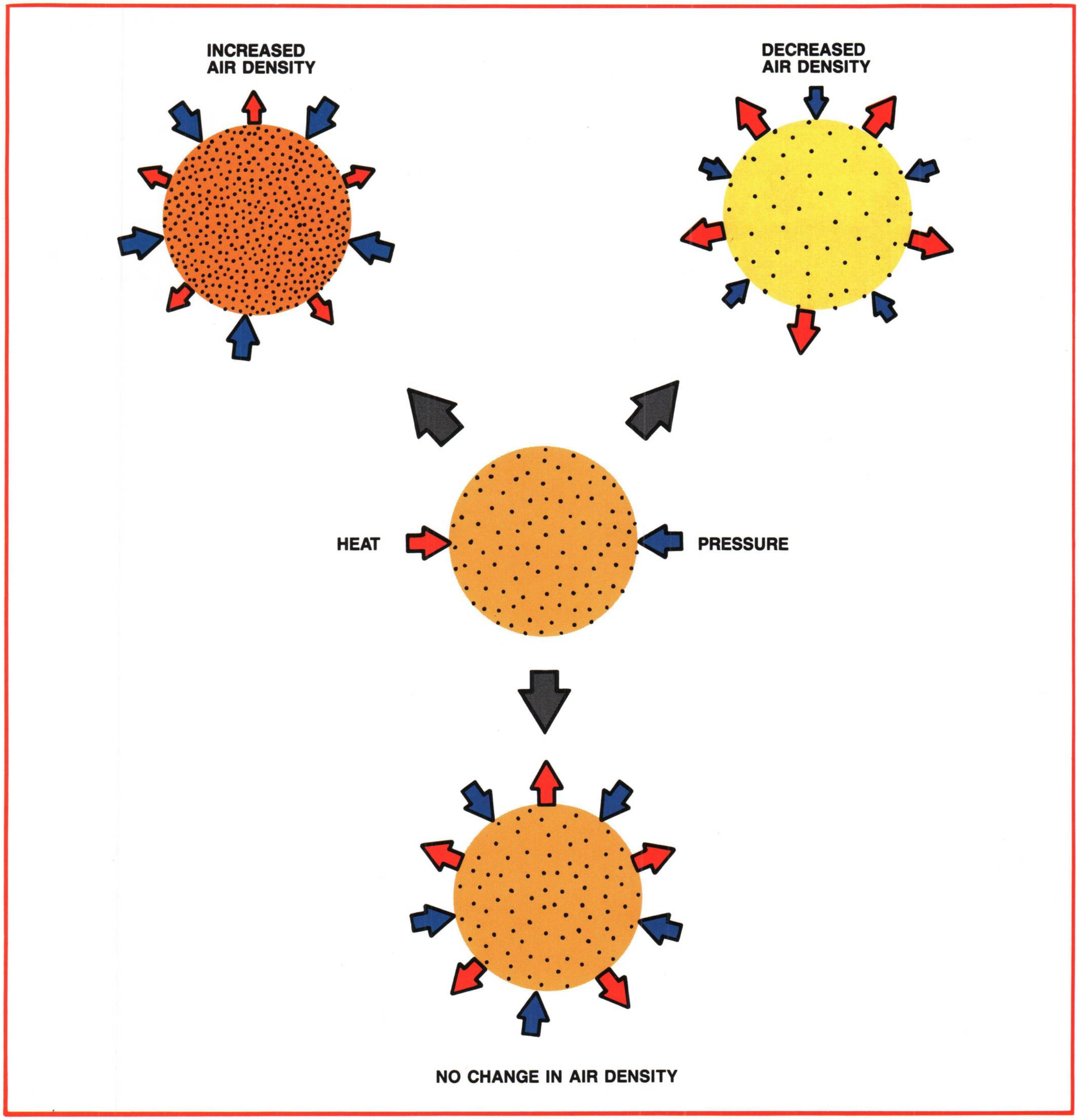

Figure 24. The Effects Of Heat And Pressure On Density

Intercooling

The best way to keep intake temperature down is by cooling the intake air. Intercooling is the process of cooling the air or air-fuel charge before it reaches the combustion chamber. The air or air-fuel charge is cooled as it passes through a heat exchanger, or intercooler (figure 25). An intercooler typically uses air or engine coolant as a cooling medium. The temperature drop through an intercooler will vary according to the temperature of the cooling medium and its flow rate. An intercooler is usually placed between the supercharger and the engine.

Intercooling provides two benefits. By cooling the air-fuel charge, an intercooler increases its density, allowing a greater quantity of air to enter an engine. This allows a larger amount of air-fuel mixture to be converted to power. Intercooling also reduces the thermal loading on an engine. The stress on valves and pistons is reduced, and there is less heat for the engine to dissipate. But even when an intercooler is used, the increased temperature of supercharged air can cause premature detonation.

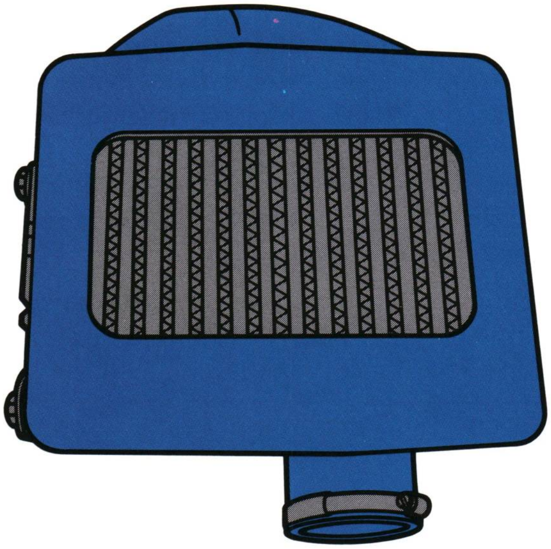

Figure 25. Intercooler

Detonation Control

Detonation is the uncontrolled burning of fuel in a combustion chamber. Detonation control becomes important on a supercharged engine because of the increased temperature of the air-fuel charge. Detonation is usually caused by an overheated mixture which explodes during the compression stroke before normal ignition begins. Because the force resulting from detonation is not properly timed, it can do serious damage to the engine.

Limiting the amount of boost pressure sent to a cylinder will help prevent a premature detonation. When the boost pressure is limited to a predetermined amount, there is less chance of an air-fuel charge burning in an uncontrolled manner. A blow-off valve can be used to control the boost pressure supplied by a supercharger (figure 26). Usually installed between the supercharger and the engine, blow-off valves bleed off part of the air-fuel mixture. Springs hold the valve shut. When the maximum allowable boost pressure is reached, these springs allow the blow-off valve to vent the excess boost pressure back to the supercharger.

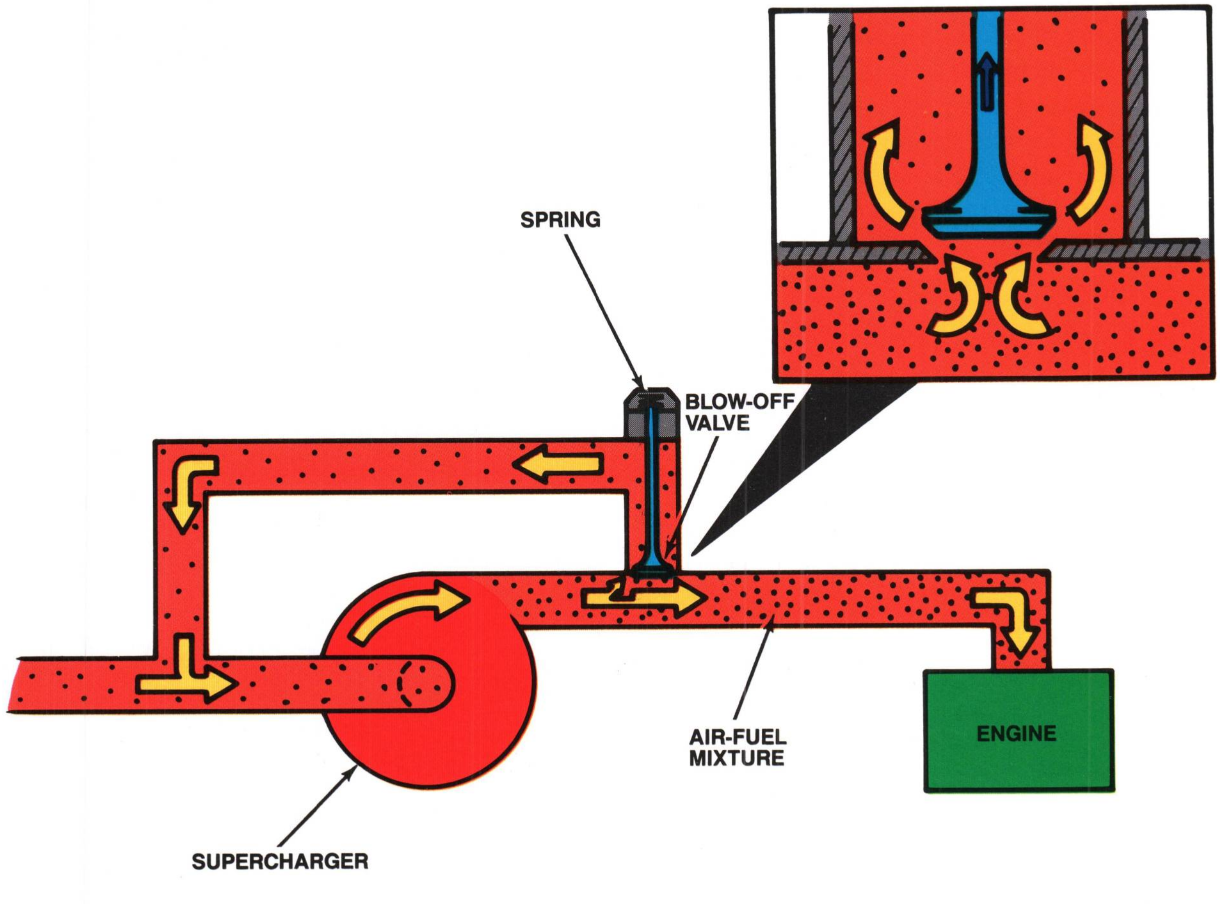

Figure 26. Blow-Off Valve

GENERAL DESCRIPTION

Superchargers are usually driven by the crankshaft through a drive belt, although some systems may use a gear or chain (figure 27). A supercharger receives power in the same manner as an alternator. The drive belt turns a pulley attached to the supercharger housing. The size of the pulley determines the supercharger drive ratio. A small pulley turns a supercharger faster than a large pulley. The faster a supercharger is turned, the more air it pumps out. Since the speed of a supercharger determines how much air is pumped, the size of the pulley will depend on the amount of air which best suits an intake system.

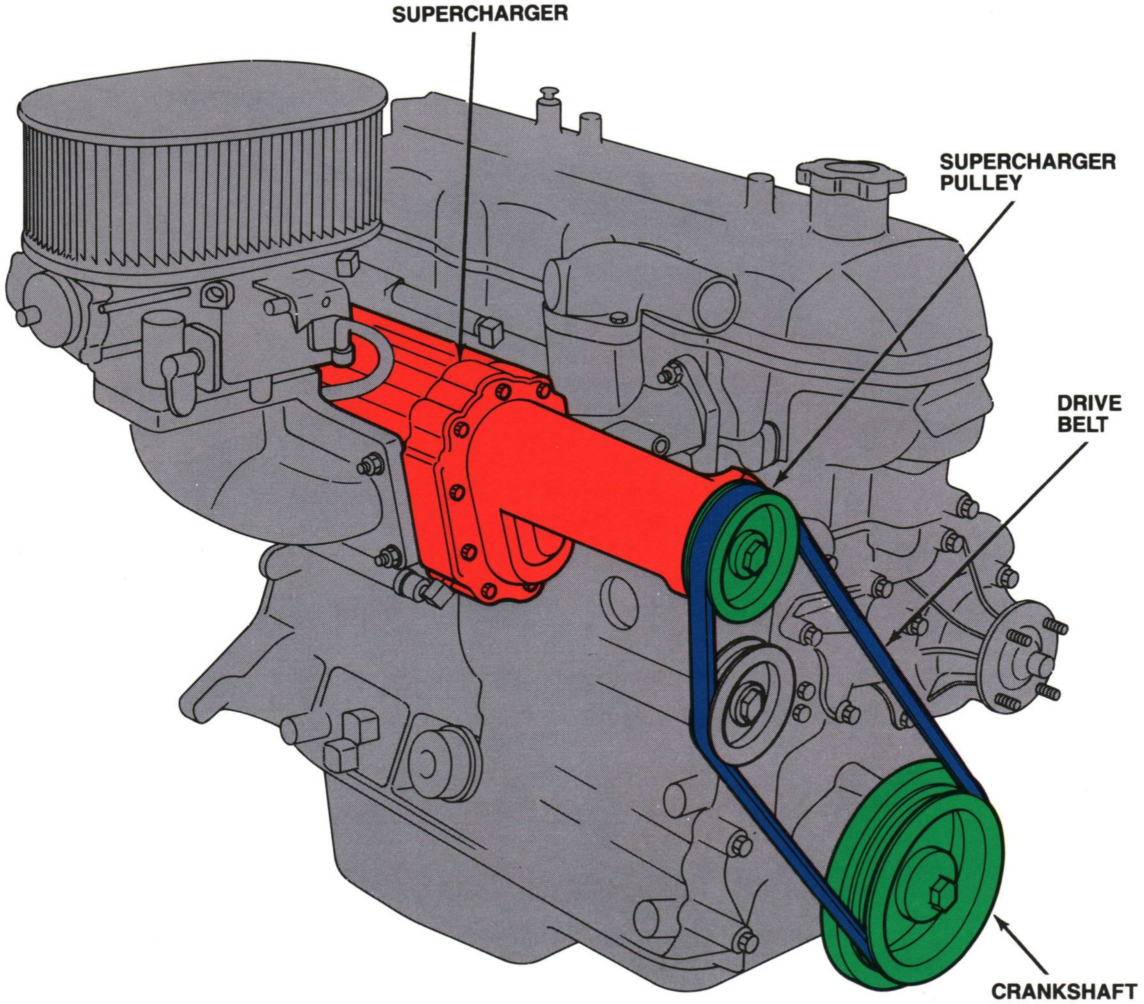

Figure 27. Belt-Driven Supercharger

On diesel and fuel-injected engines, superchargers pump air directly into the intake manifold. Carbureted engines can be supercharged using either of two possible systems. The most popular is the draw-through system, where the supercharger is mounted between the carburetor and the intake port (figure 28). A draw-through system allows the supercharger to draw the air-fuel charge from the carburetor and pump it into the intake manifold. This arrangement helps atomize the fuel particles in the air-fuel charge by mixing it as it passes through the supercharger. This promotes a more even and complete combustion, as well as cleaner burning in terms of emissions.

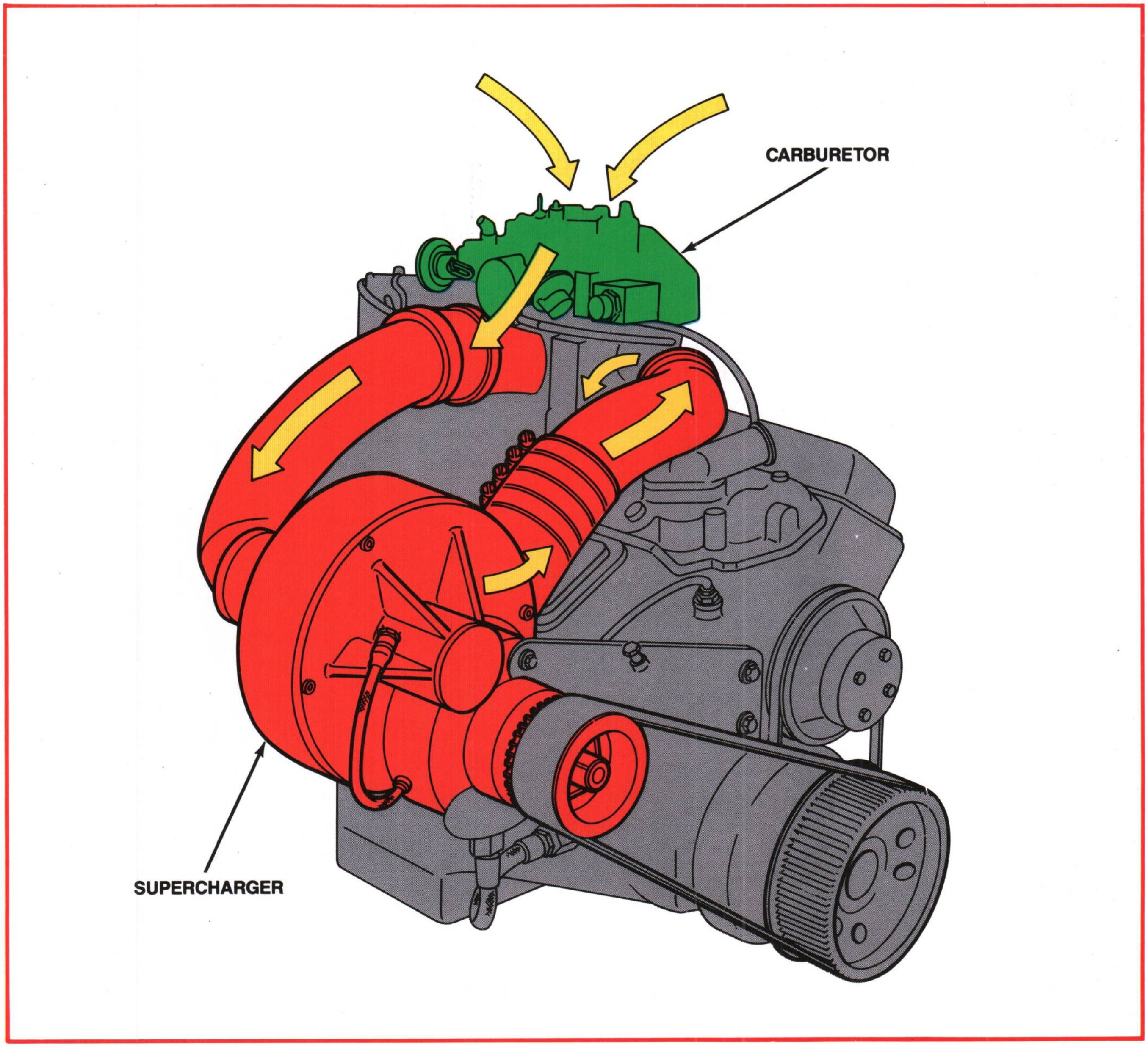

Figure 28. Draw-Through Supercharging System

Another arrangement on a carbureted engine is the blow-through system (figure 29). On a blow-through system, the supercharger is mounted between the air filter and the carburetor. This system blows air through the carburetor and into the intake manifold. The carburetor must be encased in a pressure box or bonnet to work properly in a blow-through system. The air around the carburetor has to be pressurized, otherwise the main jets will not deliver fuel into the intake airstream. This is because the carburetor requires a pressure drop at the venturi to siphon fuel from the bowl.

The placement of a supercharger in an air intake system will often depend on the design of the air intake system, as well as the type of supercharger used. Some superchargers operate best in a draw-through system, while others work well blowing air into the carburetor. Though there are several different types of superchargers, they can be separated into two groups: positive displacement and dynamic.

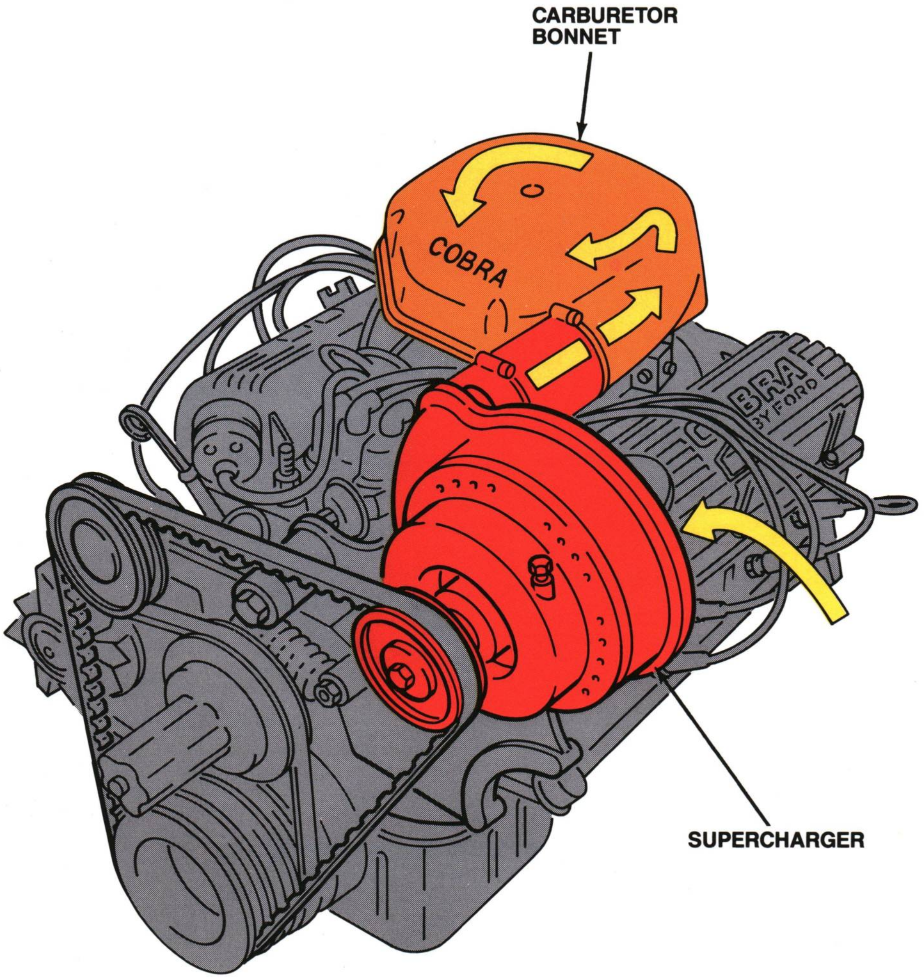

Figure 29. Blow-Through Supercharging System

POSITIVE DISPLACEMENT SUPERCHARGERS

Positive displacement superchargers deliver the same volume of air during each revolution, regardless of engine speed. For this reason, a positive displacement supercharger works equally well during high and low engine speeds. More air will be pumped at high engine speed because the crankshaft drives the supercharger through more revolutions per minute. But unlike a turbocharger, a positive displacement supercharger will provide a substantial amount of boost even when the engine is idling. Two types of positive displacement superchargers are commonly used: the lobe supercharger and the vane supercharger.

Lobe Supercharger

The lobe supercharger has a pair of rotors which turn inside a closed housing (figure 30).

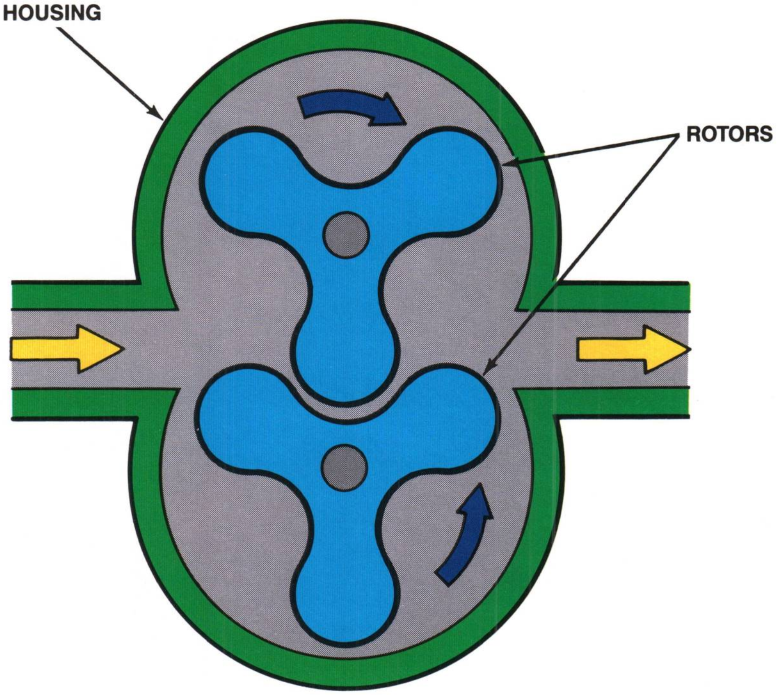

Figure 30. Lobe Supercharger

The crankshaft drives the rotors through a pulley attached to the supercharger. Most lobe superchargers have two or three lobes on each rotor (figures 31 and 32). Some rotors have straight cut lobes, others use helical cut lobes.

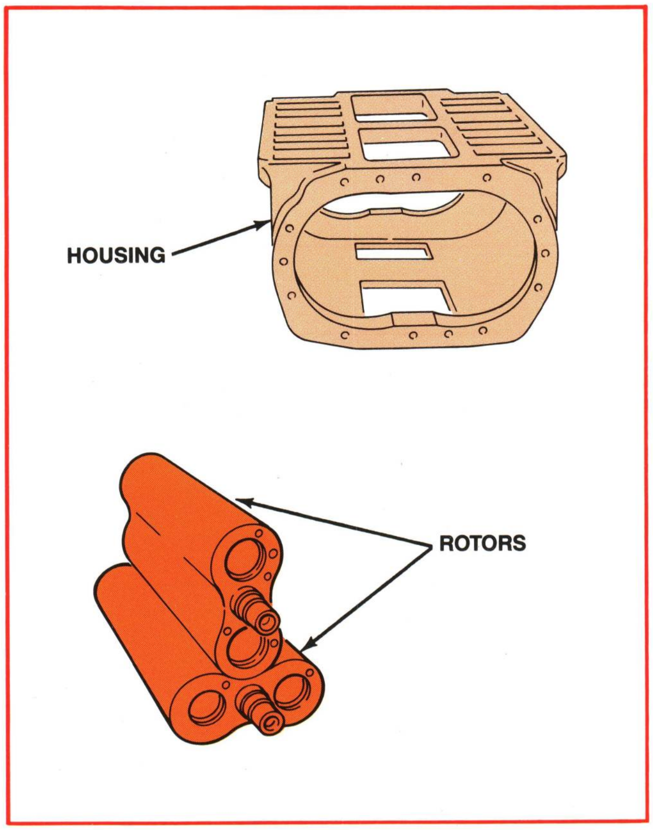

Figure 31. Two-Lobed Rotors and Housing

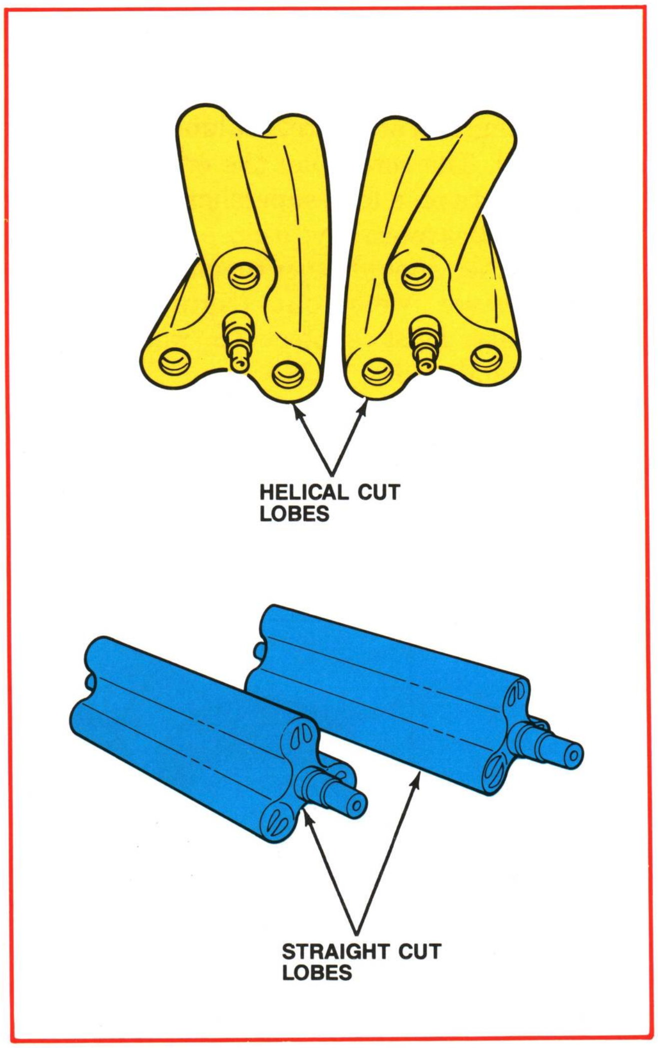

Figure 32. Three-Lobed Rotors

The rotors are phased by gears to prevent the lobes from clashing. Bearings pressed into a bearing plate reduce friction between the rotors and housing, and seals prevent lubricant leakage (figure 33). The rotors are the only two major moving parts on a lobe supercharger. Although the rotor lobes must have a close clearance to be effective, they should never touch, and therefore should never wear out (figure 34). The components most subject to wear are the bearings and seals.

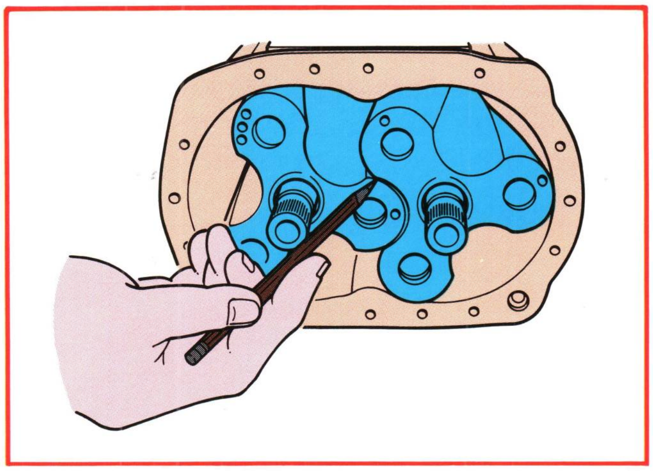

Figure 34. Lobe Clearance

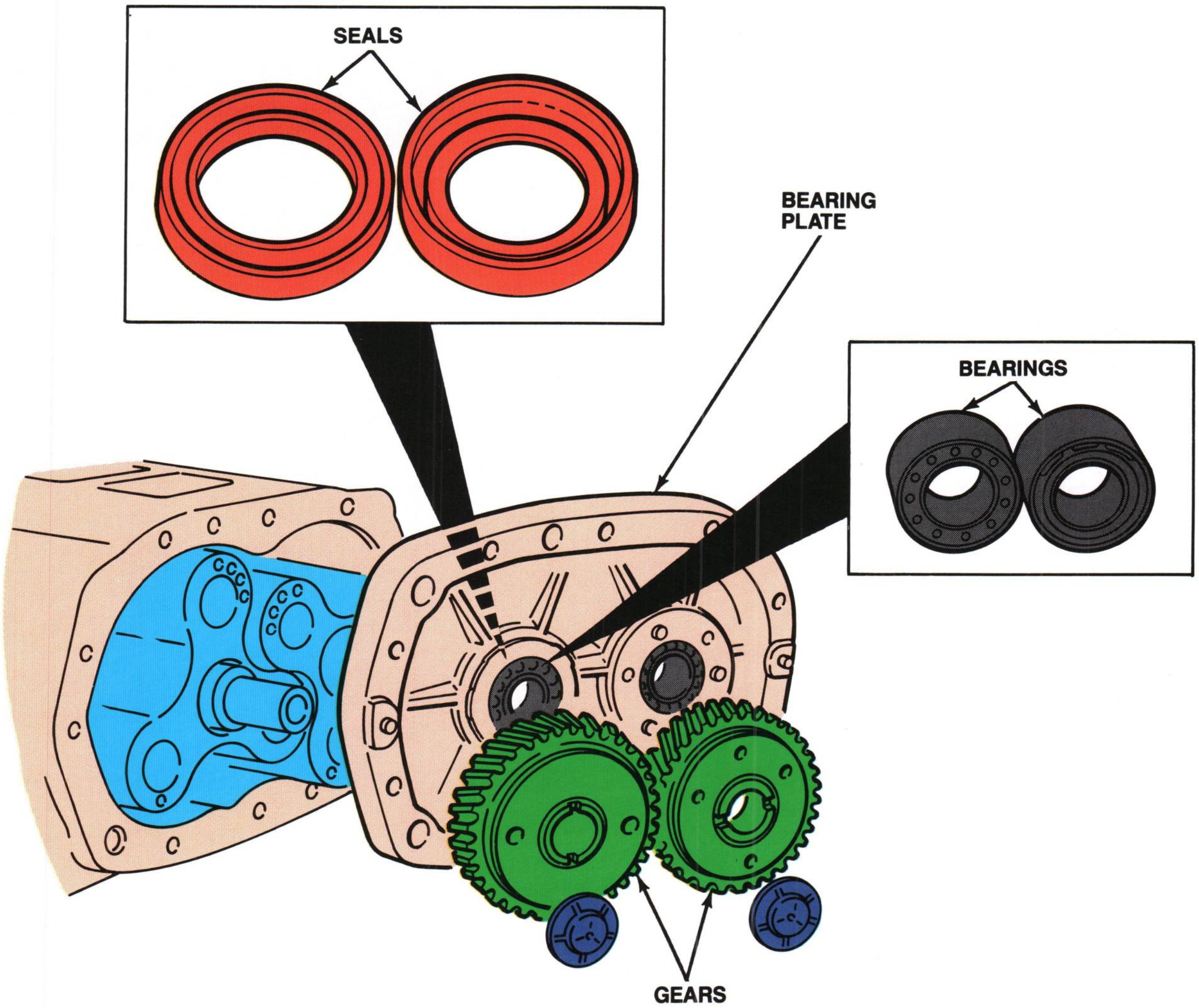

Figure 33. Rotor Drive Gears And Bearing Plate

The rotors are designed to turn in opposite directions, meshing like a pair of gears, though they do not come in direct contact with each other. As the rotors turn, air is drawn into the intake port and carried through the open space between the lobes and the housing (figure 35). The air is then pumped through the outlet port to the cylinders. The length and diameter of the rotors determine the volume of air which will be pumped during each revolution.

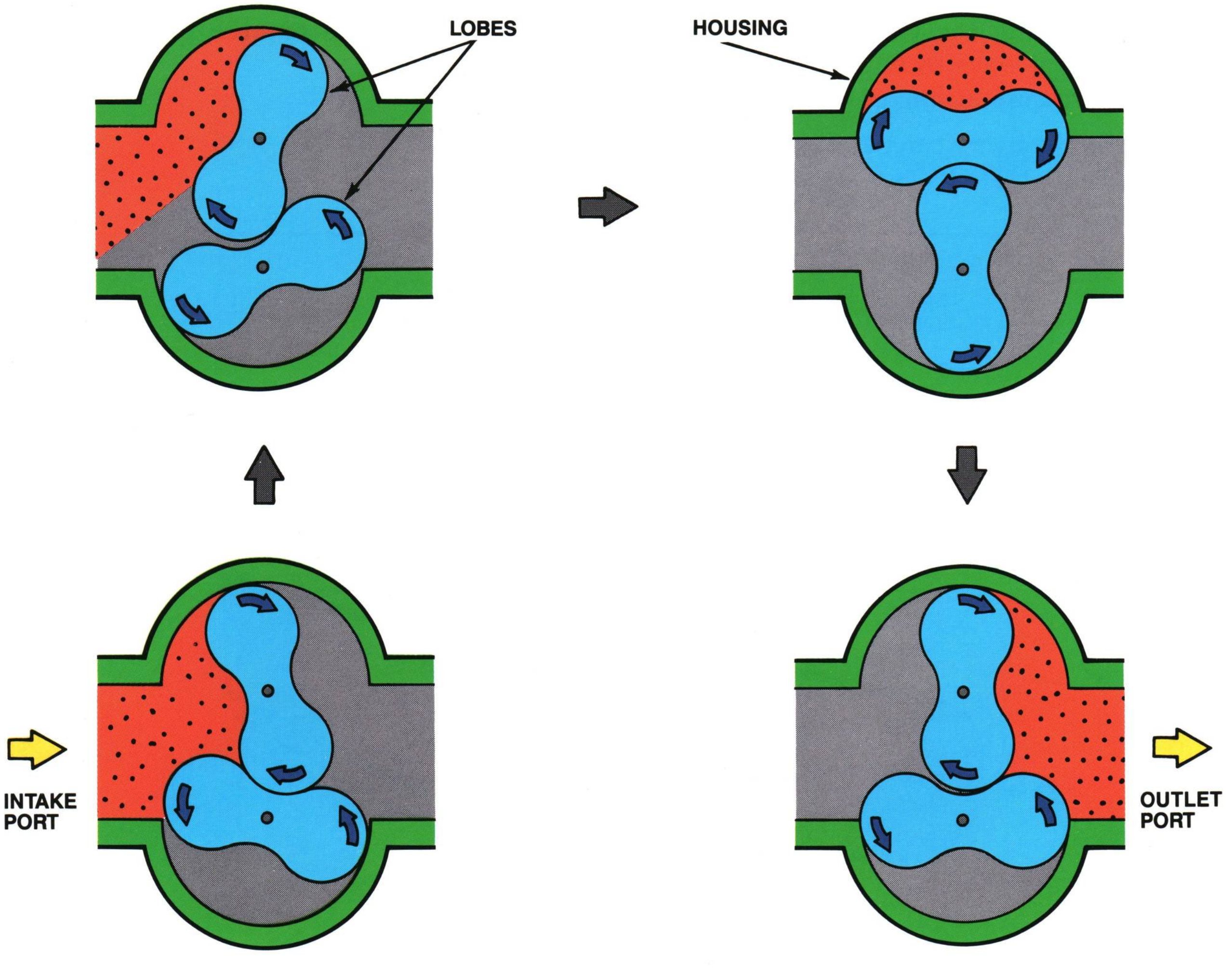

Figure 35. Lobe Airflow

All lobe superchargers have a pulsing airflow, especially at low rpm, because of the small number of lobes on each rotor. The continuous back-and-forth motion caused by the air pulses and backpressure from the cylinder creates turbulence and friction. This heats the air and lowers its density. Backpressure from the cylinder can also leak through the lobe and housing clearances, lowering the volumetric efficiency. There are several ways to improve airflow and reduce backpressure leakage.

Pulsing airflow delivery can be smoothed out by using rotors with three lobes instead of two. The three-lobed design also helps reduce backpressure leakage, since more than one rotor tip seals against the housing at the same time. Some superchargers have Teflon or nylon strips attached to the sealing edges of the lobe (figure 36). These strips reduce lobe clearance and help stop backpressure leakage. Using spiral, or twisted rotors (helical cut rather than straight cut) also smoothes out the pulsing of output airflow.

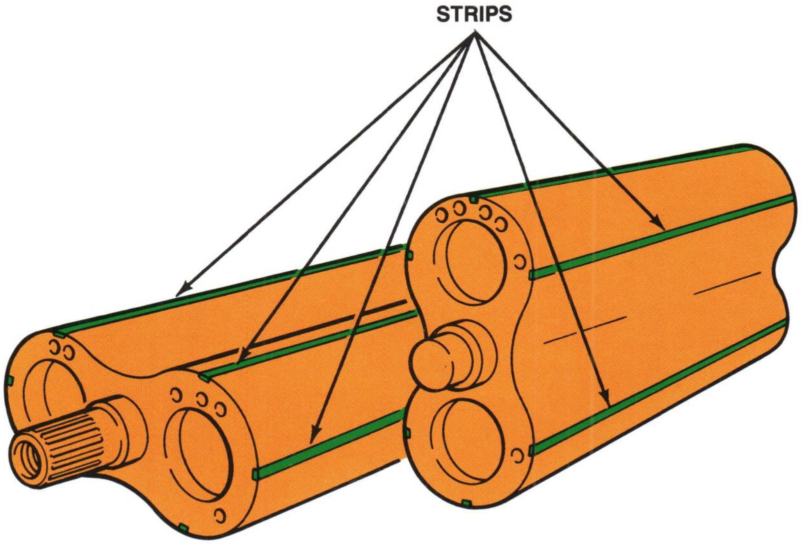

Figure 36. Rotor Strips

Under high vacuum conditions, such as driving at constant highway speeds, the lobe supercharger will use less crankshaft power. When the engine is running with the throttle closed or only slightly open, vacuum is produced in the intake manifold. This vacuum turns the rotors like a windmill, and less crankshaft power is used.

On carbureted engines, the lobe supercharger operates best in a draw-through system, where it pumps air directly into the intake port. The lobe supercharger is also well-suited for blowing fresh intake air into two-stroke diesel engines. Because a two-stroke engine has no intake or exhaust stroke, it needs an external source to move air through its system. The lobe supercharger is commonly called a "blower" for this application because it blows in fresh air and forces out exhaust before the compression stroke begins (figure 37).

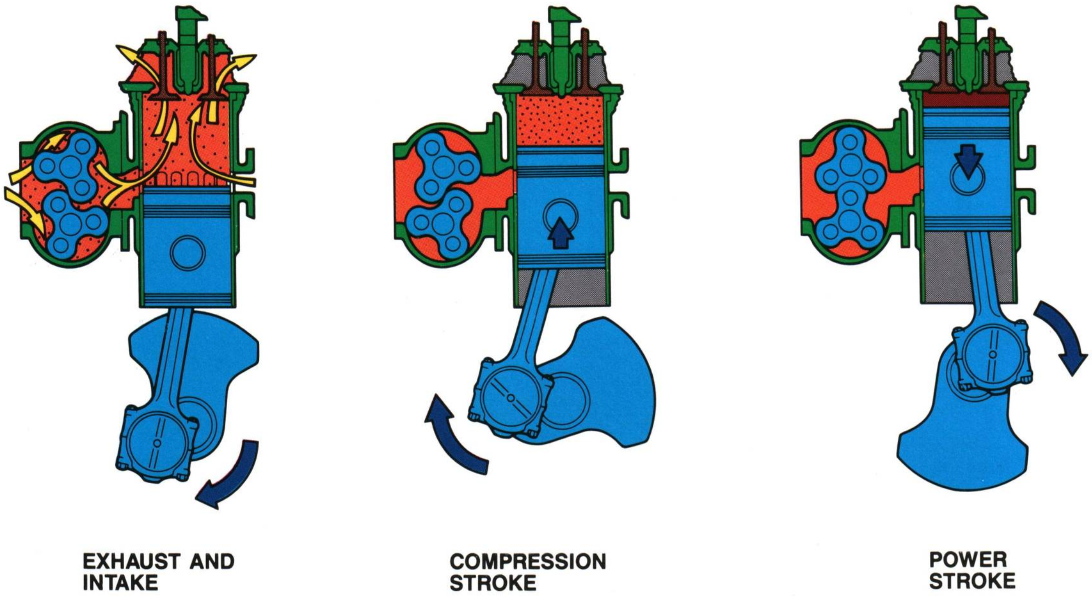

Figure 37. Two-Stroke Blower Operation

The gears and bearings on a lobe supercharger require lubrication. Since an oil pressure feed is not required, the oil can be separate from the engine oiling system. Such a system would have oil reservoirs within the front and rear housings of the supercharger. An example of lubricating a lobe supercharger using the engine oiling system is shown in figure 38. Seals between the bearings and rotors ensure that airflow remains oil-free.

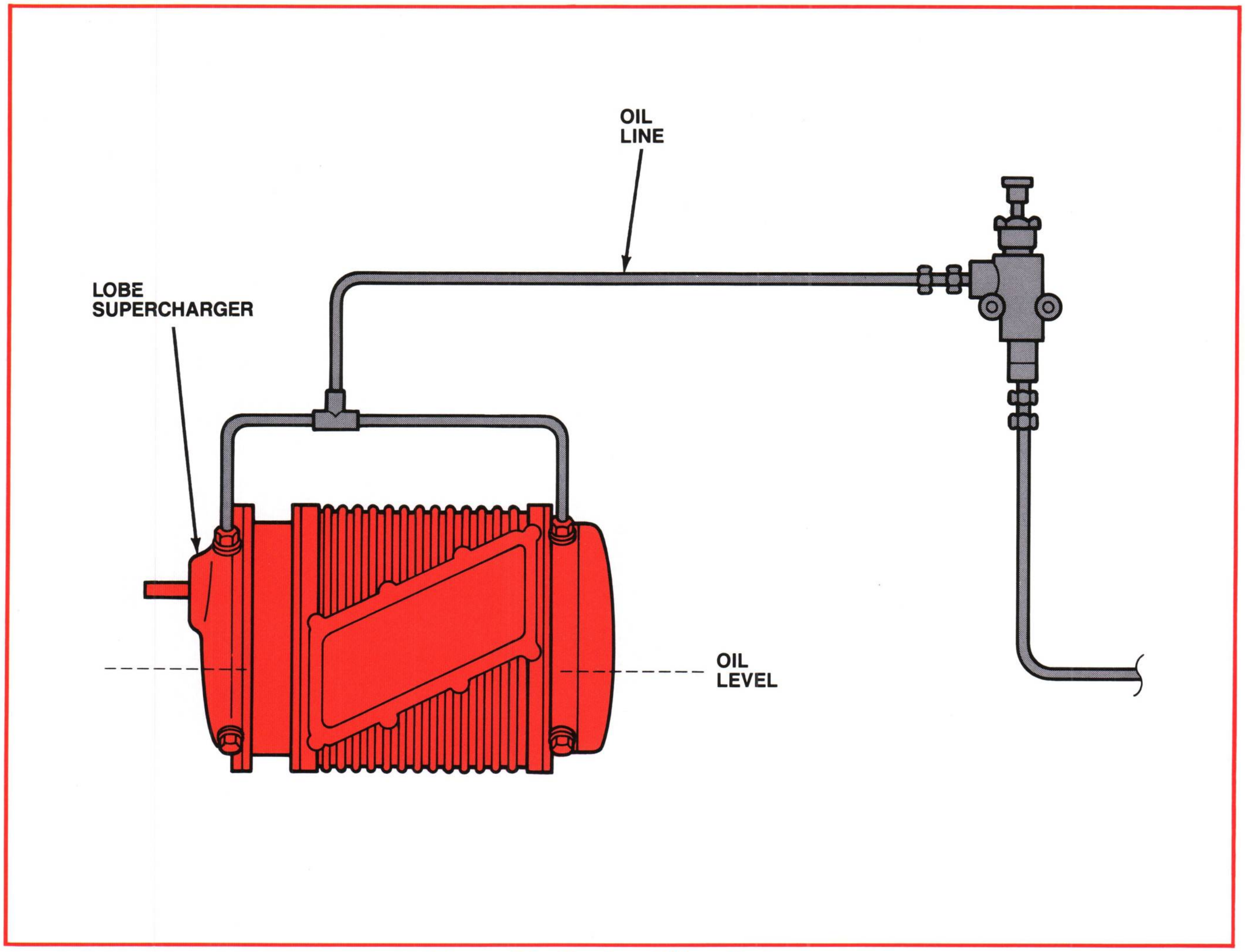

Figure 38. Engine Oiling System

Vane Supercharger

There are several varieties of the vane supercharger, but it is basically a cylindrical housing with a single rotor that rotates on an offset axis. The rotor is slotted for any number of protruding vanes (figures 39 and 40). The vanes maintain a near or light contact with the walls of the housing. As the rotor spins, the vanes sweep the air into the housing through the inlet port.

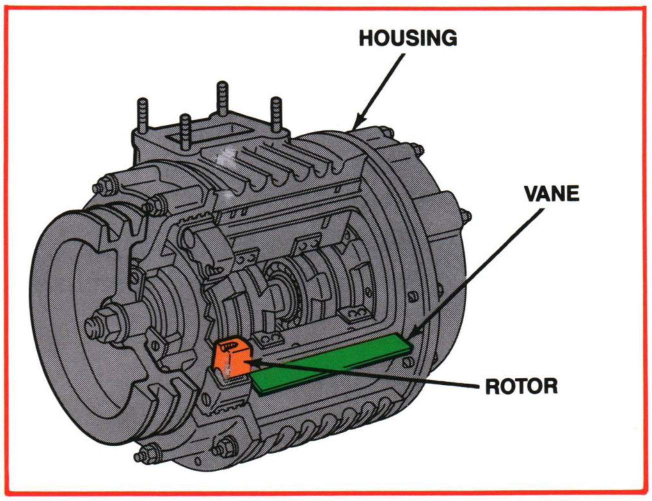

Figure 40. Shorrock Vane Supercharger

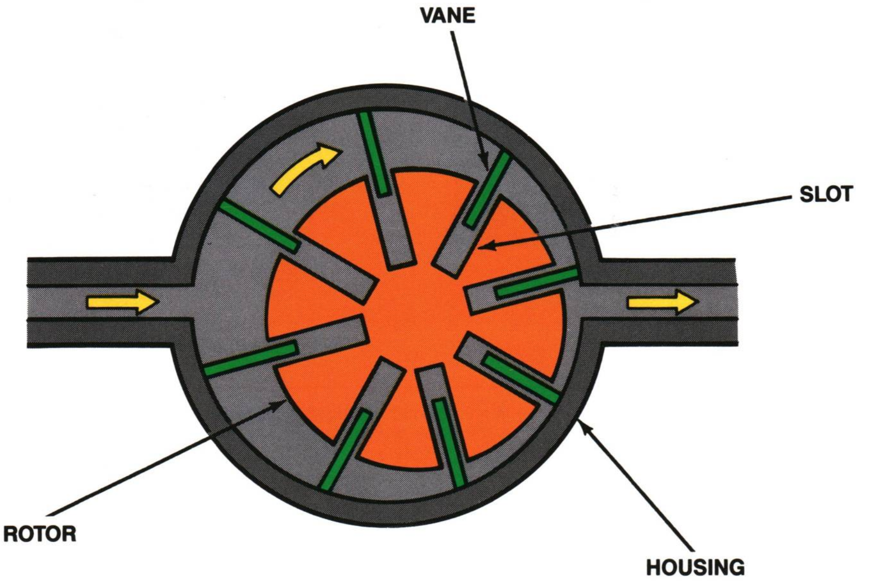

Figure 39. Vane Supercharger

The open space between the vanes carries the air towards the outlet port (figure 41). At the same time, as the offset rotor moves closer to the housing while it spins, it compresses the air trapped between the vanes. The air is pumped through the outlet port.

Unlike the lobe supercharger, which simply forces air into the cylinders, the vane supercharger compresses the air within its housing before forcing it through the outlet port. This internal compression allows the vane supercharger to create higher boost pressures than external compression superchargers without losing efficiency. The vane type is used most successfully when supercharging small engines at high boost pressures.

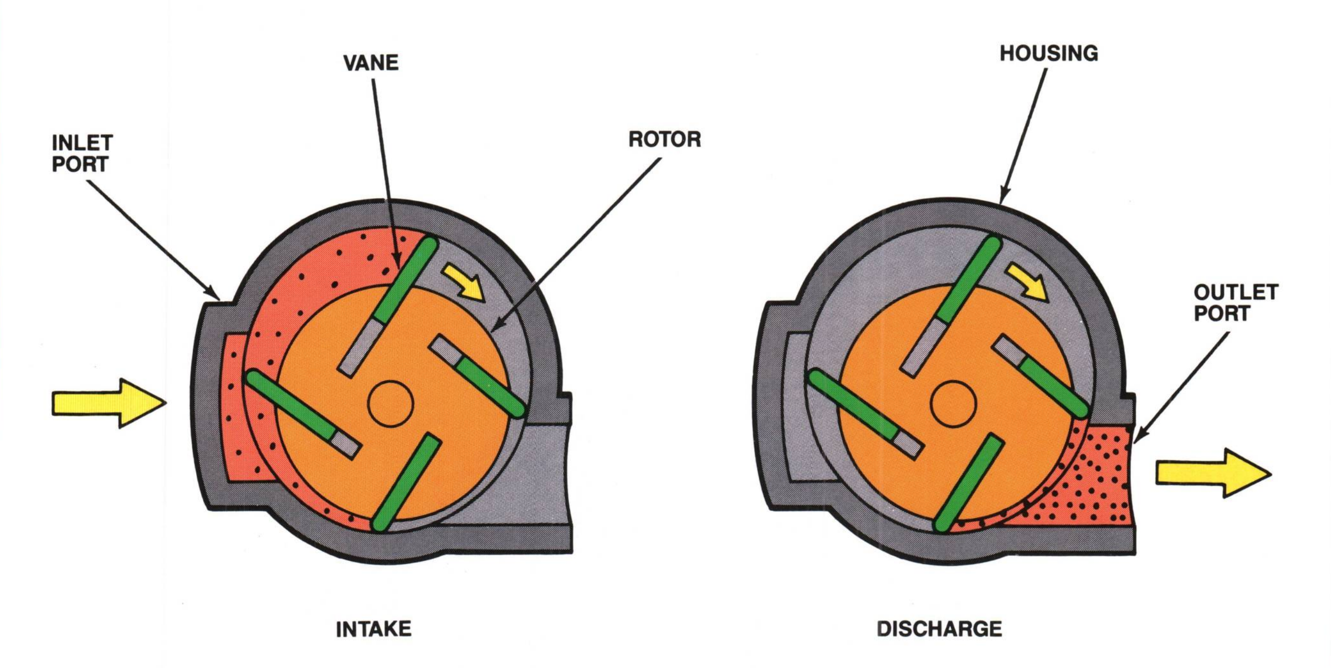

Figure 41. Vane Airflow

DYNAMIC SUPERCHARGERS

The operation of a dynamic supercharger is similar to that of a turbocharger. The faster the crankshaft turns this type of supercharger, the better it operates. The centrifugal type is a dynamic supercharger whose pumping output increases roughly as a square of the engine speed. This means that when the engine speed is doubled, the supercharger provides four times as much boost pressure. If the engine speed is tripled, the supercharger provides nine times as much boost pressure. This type of operation has its advantages and its drawbacks. Let's look at an example.

A centrifugal supercharger which provides three pounds of pressure (per square inch) at an engine speed of 2000 rpm will provide 12 pounds at 4000 rpm. This is a substantial increase in boost pressure, but the reverse holds true at lower engine speeds. Using the same example, less than one pound of pressure will be produced at 1000 rpm. For this reason, a dynamic supercharger operates best at higher rpms. Three kinds of dynamic superchargers are typically used: the centrifugal, axial flow and pressure-wave supercharger.

Centrifugal Supercharger

A centrifugal supercharger moves air using a bladed fan, or impeller (figure 42).

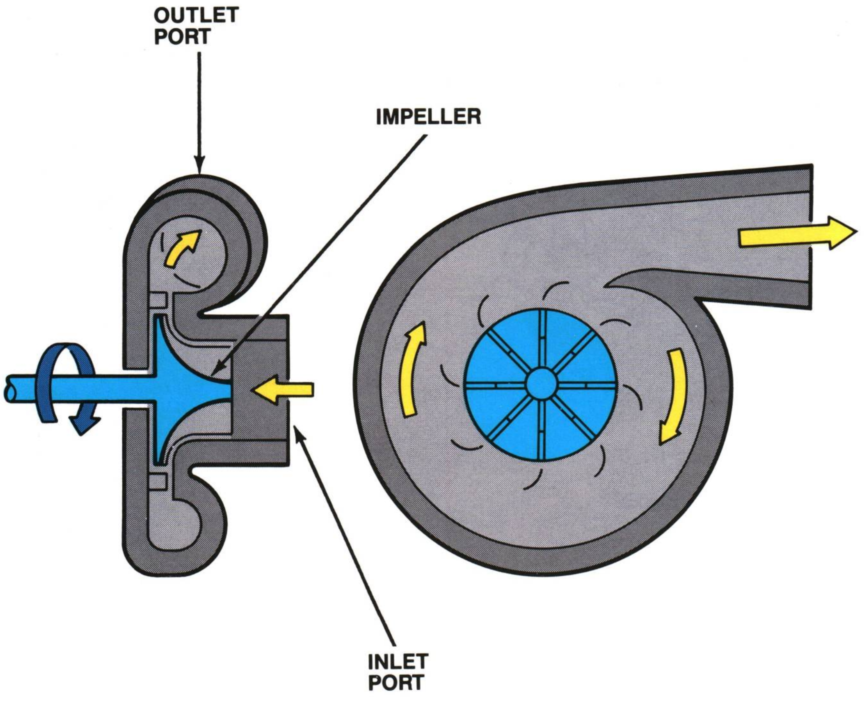

Figure 42. Centrifugal Supercharger

The impeller is housed within a circular casing (figure 43). Air enters an inlet port located at the center of the impeller. From that point it is accelerated by centrifugal force by the spinning blades and pumped out the outlet port (figure 44).

A centrifugal supercharger does not heat the air as much as a lobe supercharger, and the airflow is much smoother. There is very little stress on the impeller because it is lightweight and does not mesh or come in close contact with any other moving parts. The impeller must be driven at high rotational speeds to provide adequate boost pressure. Impeller speeds of 50,000 rpm are not uncommon. For this reason, centrifugal superchargers, like turbochargers, require high quality shaft bearings and a good lubrication system.

Turbochargers are a type of centrifugal supercharger; the only difference is that they are driven by engine exhaust rather than a belt connected to the crankshaft. A relatively small centrifugal supercharger can produce a substantial boost pressure. Like the turbocharger, the centrifugal supercharger gives its best boost pressure at high engine speed. However, a centrifugal supercharger also provides substantial boost pressure when the engine is idling.

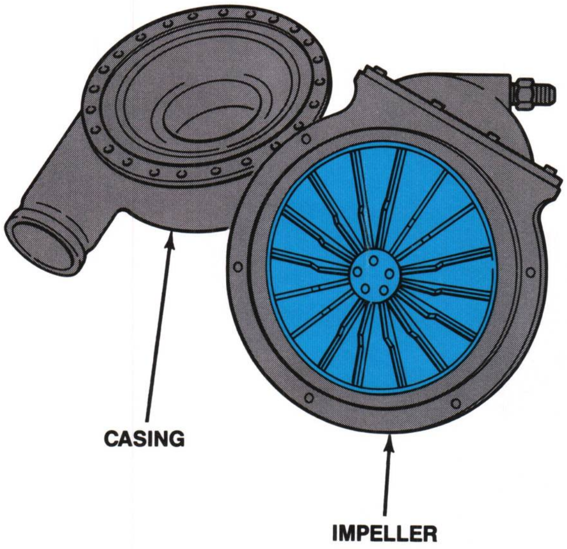

Figure 43. Impeller and Case

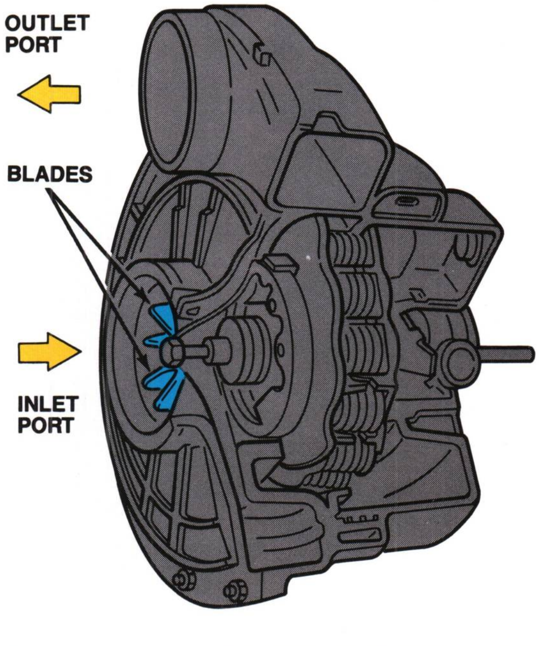

Figure 44. Centrifugal Airflow

Axial Flow Supercharger

The axial flow supercharger was introduced by the Latham Manufacturing Company in 1956 (figure 45). It consists of a cylindrical rotor housed within a casing, or stator (figure 46). The rotor is the major moving component on an axial flow supercharger. The rotor is spun by a drive belt attached to the crankshaft.

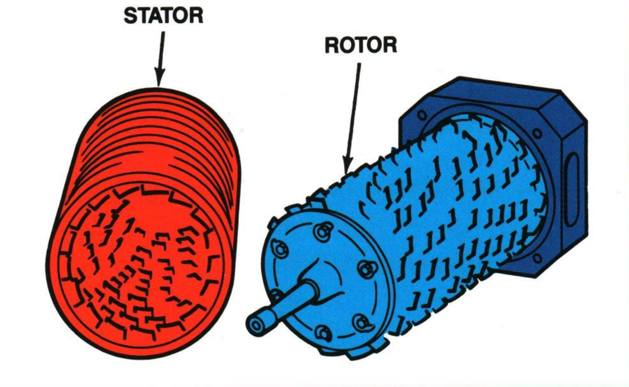

Figure 46. Rotor And Stator

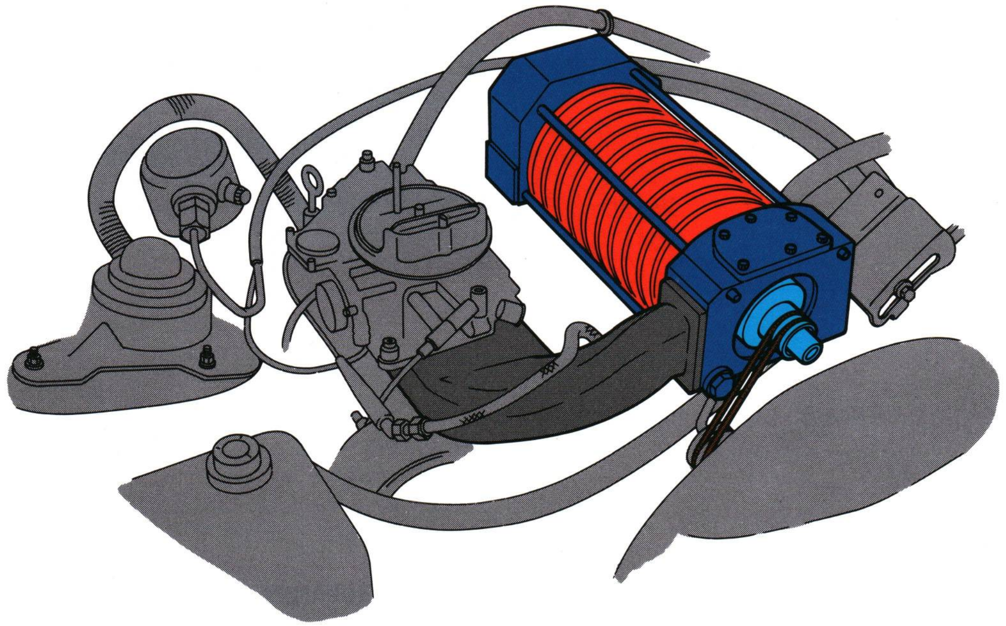

Figure 45. Latham Axial Flow Supercharger

Around the circumference of the rotor is a series of curved fan blades (figure 47). These blades accelerate the air drawn in through inlet ports. On the inside of the stator are vanes curved in the opposite direction of the blades on the rotor. The vanes catch the accelerated air and change its direction, stepping up the pressure. The compressed air is then accelerated by the next set of rotor blades, compressed again by the next row of stator vanes, and so on until it is forced through the outlet port and into the intake manifold.

The axial flow supercharger can produce as much as ten pounds (per square inch) of boost pressure using very little engine power. The elaborate machining required to manufacture the rotor and stator has limited the use of the axial flow supercharger in the automotive field.

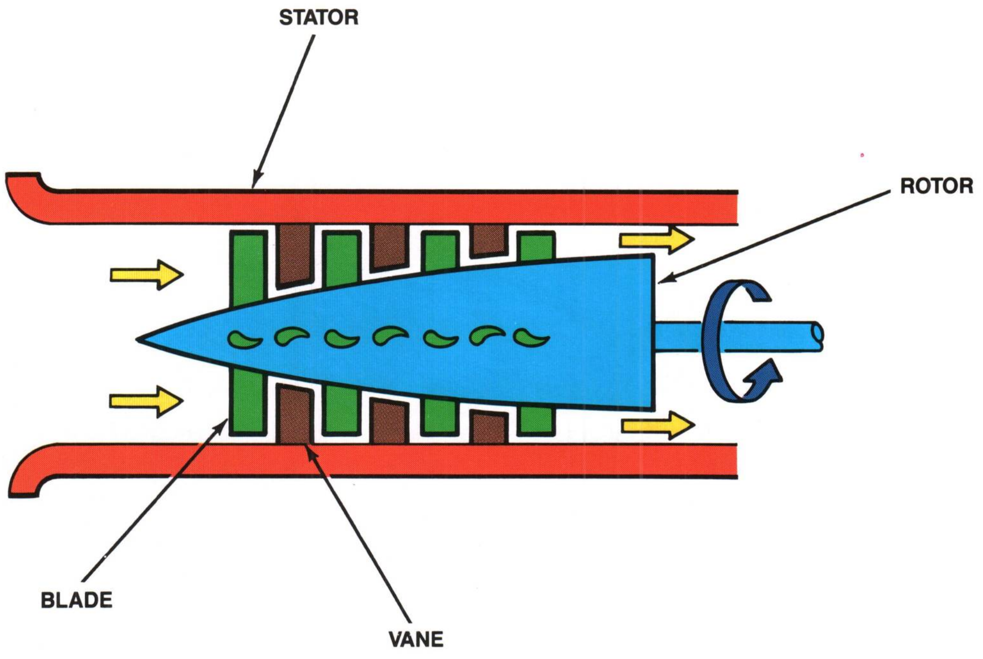

Figure 47. Axial Flow Supercharger

Pressure-Wave Supercharger

The pressure-wave supercharger combines the best features of an exhaust-driven turbocharger and a belt-driven supercharger (figure 48). The main component of the pressure-wave supercharger is a cylindrical rotor. Like the turbine of a turbocharger, this rotor must be made of high quality material to withstand exhaust temperatures. The rotor is the only moving part in the system. It is spun by a drive belt at up to twice the crankshaft speed.

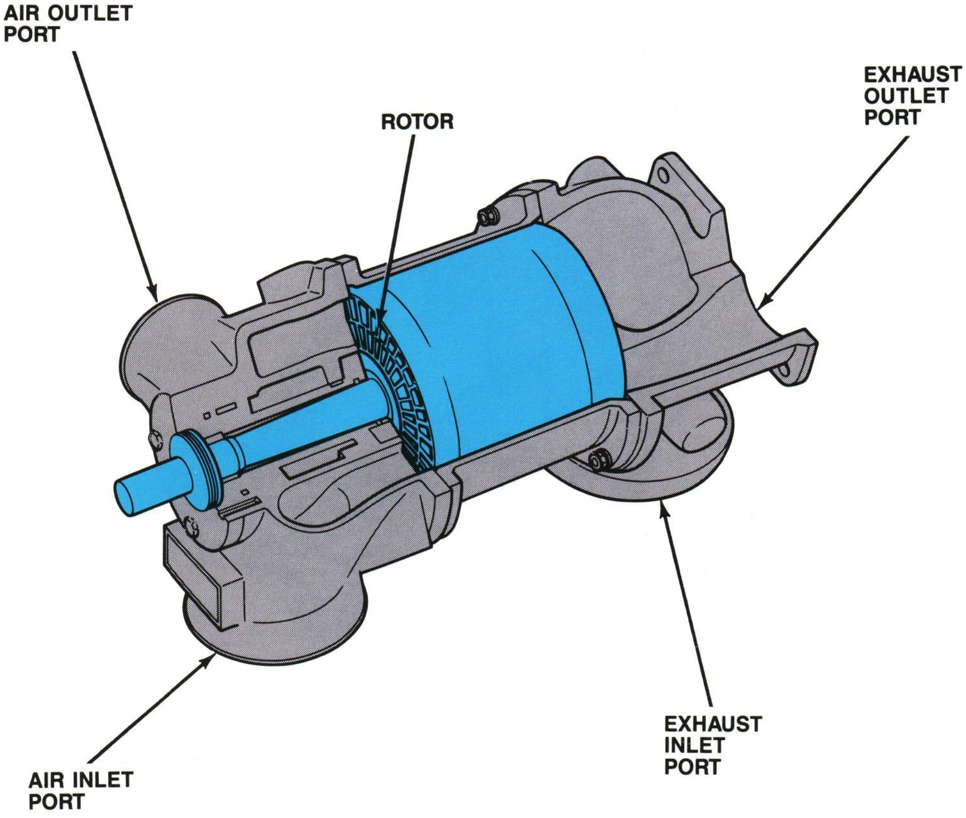

Figure 48. Comprex Pressure-Wave Supercharger

Within the rotor are a series of longitudinal cavities, similar to a honeycomb. These cavities run through the length of the rotor. The pressure-wave supercharger is set up much like a turbocharger, with air inlet and outlet ports on one side of the rotor, and exhaust inlet and outlet ports on the other (figure 49). The best way to understand how a pressure-wave supercharger operates is to follow a cavity through one rotation of the rotor.

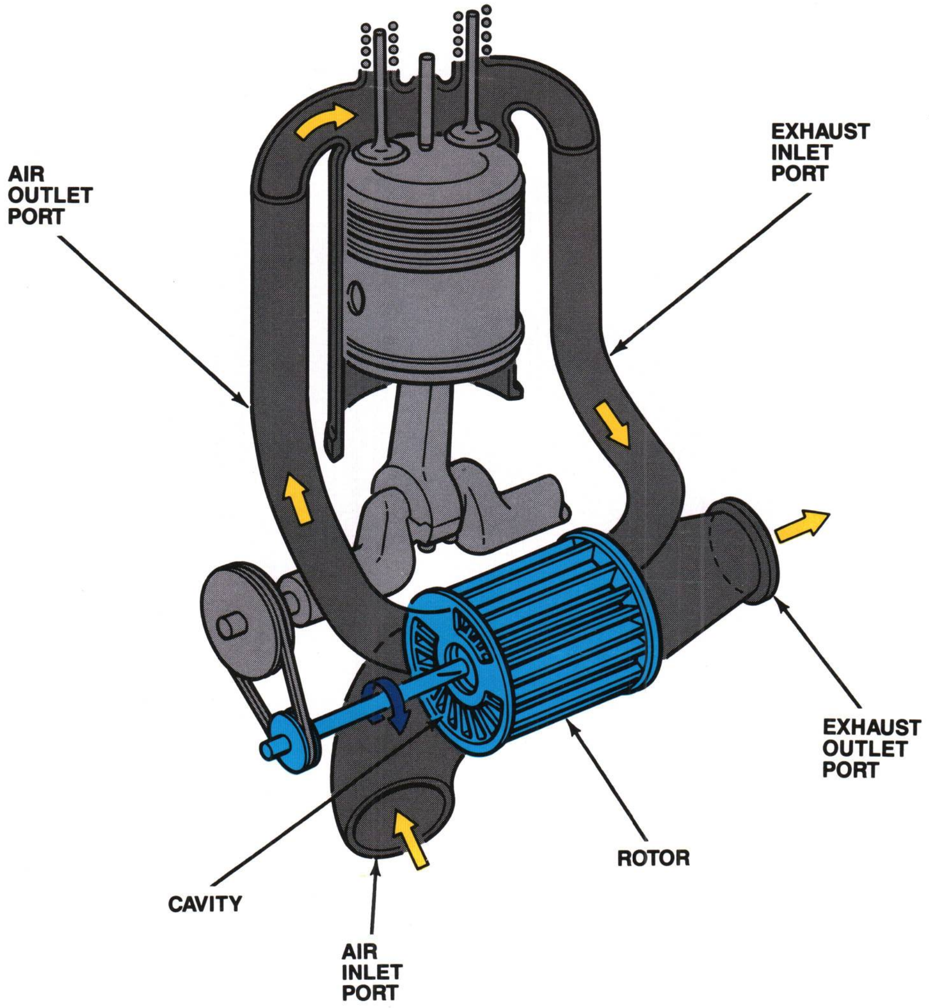

Figure 49. Pressure-Wave System

Air Intake

At one end of the rotor is an air inlet port. Air enters the cavity from this inlet port (figure 50). As the belt turns the rotor, the cavity moves past the air inlet port, sealing off that end of the cavity.

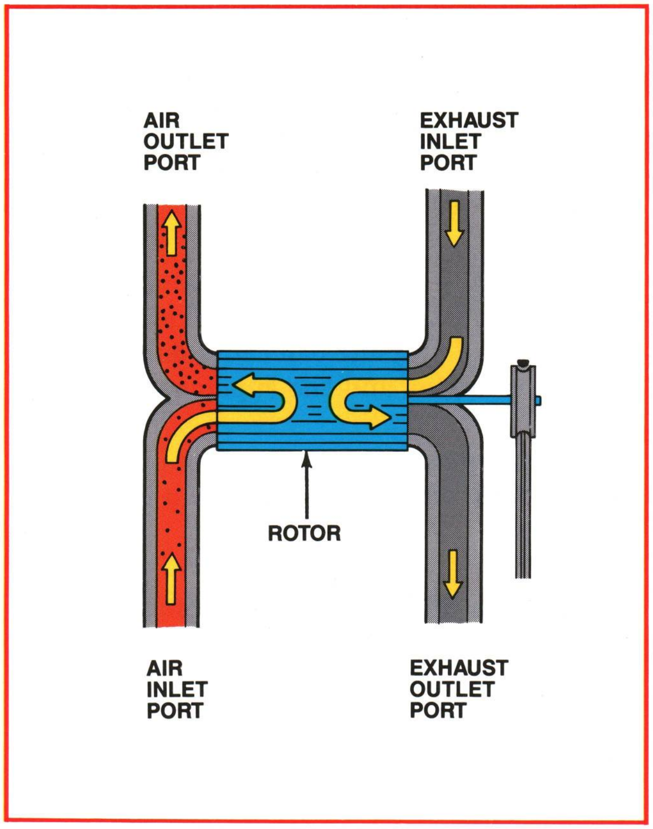

Figure 50. Pressure-Wave Airflow

Exhaust Intake

Once the air inlet port is sealed off, the rotation of the rotor causes the other end of the cavity to pass an exhaust inlet port. The hot, expanding exhaust gas enters, pushing the air that is already in the cavity to the far end. In other words, the exhaust gas compresses the intake air within the cavity.

Air Discharge

The rotor continues to turn, and the cavity passes the air outlet port. The now-pressurized air is forced into the intake manifold or carburetor. The cavity moves past the outlet port before the exhaust gas can escape.

Exhaust Discharge

The rotation of the rotor now brings the other end of the cavity to an exhaust outlet port. This allows the still-expanding exhaust gas to reverse direction and escape through the outlet port to the exhaust pipe. Once the exhaust gas reverses direction and begins to move out this port, the rotor turns to a position which uncovers a scavenger port at the other end of the cavity. The evacuating exhaust gas draws fresh air into the cavity. The air purges any residual exhaust gas. When the cavity revolves past the exhaust outlet and scavenger ports to the air inlet port, the cycle is repeated.

The pressure-wave supercharger has been used primarily on two-stroke diesel engines. Since the power used to compress the intake air is derived from exhaust gases, the pressure-wave supercharger uses engine power only to turn the rotor. The timing and delivery rate of boost pressure to the engine is determined by the rotational speed of the rotor.

Summary

We have reviewed several types of superchargers. Some of these types may appear on future Ford vehicles. Recent emphasis on the research and development of superchargers is paving the way to more efficient supercharging systems. With the growing interest in compact cars and high performance, supercharging is likely to be an attractive and widely used option in the years to come.

GLOSSARY

Boost — The term used for pressure produced by a supercharger when it increases airflow into the combustion chamber. Boost is usually measured in pounds per square inch (psi).

Centrifugal Force — A force tending to pull an object outward when it is rotating rapidly around a center.

Compressed Air — Air reduced in volume by pressure. When air is compressed, the molecules create friction, which creates heat.

Charge — The mixture of air and fuel which enters the cylinder for combustion.

Density — The mass or weight of a substance in a region of space.

Detonation — The uncontrolled burning of fuel in the combustion chamber.

Intercooler — A device used to cool supercharged air before it enters the intake manifold.

Intercooling — The term used for the process of cooling supercharged air.

Impeller — The component which draws air into a centrifugal supercharger.

Normally Aspirated — The method by which an internal combustion engine draws air into the combustion chamber. As the piston moves downward in the cylinder, it creates a vacuum which draws air into the combustion chamber through the intake manifold.

Overboost — An excessive amount of pressure created by the supercharger. An overboost of pressure can cause damage to both the engine and the supercharger.

Supercharging — The process of pumping air through an intake system and into the cylinders.

Volumetric Efficiency — A comparison of the amount of air that an engine could draw in to the amount that it actually draws in under normal operating conditions.

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